COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

JAN 6 19[illegible]

GINEERING
LIBRARY

December, 1949

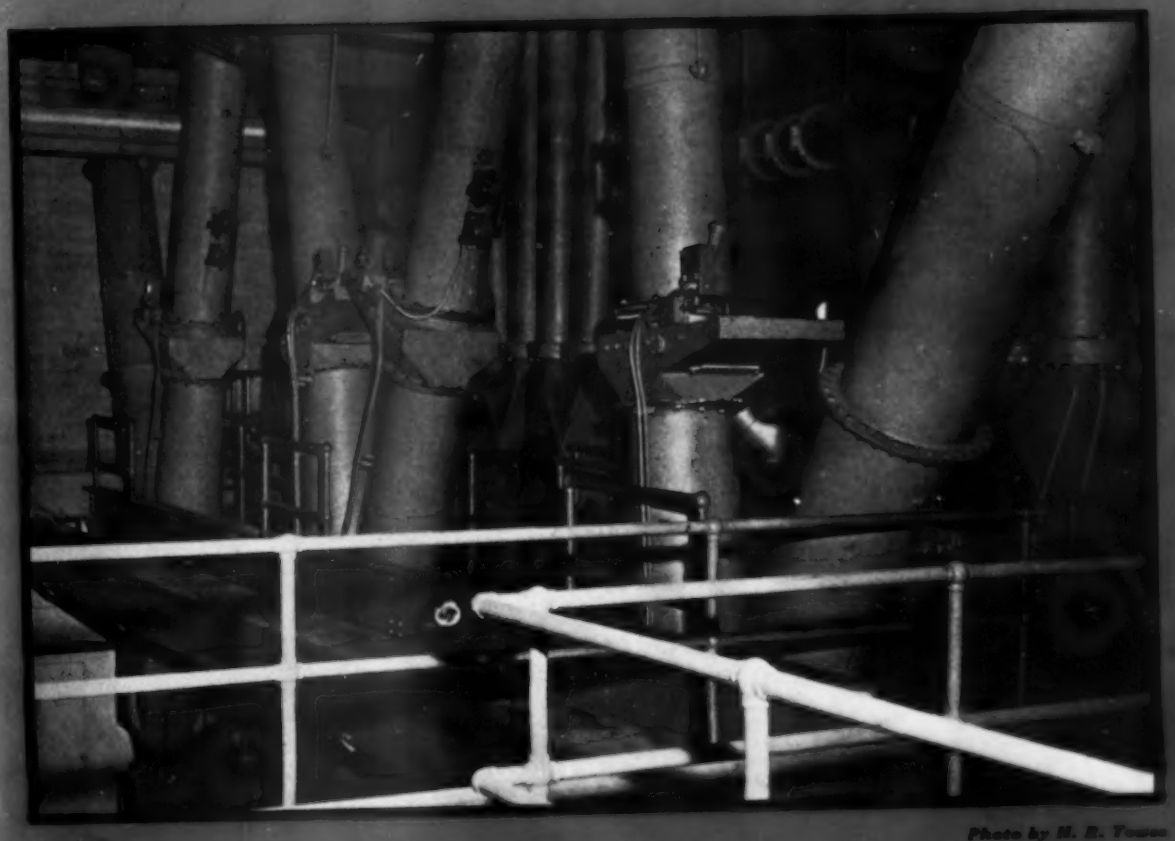


Photo by H. R. Toone

Coal Chutes With Gates and Vibrator Controls

Steam Plant at Susquehanna Mills ▶

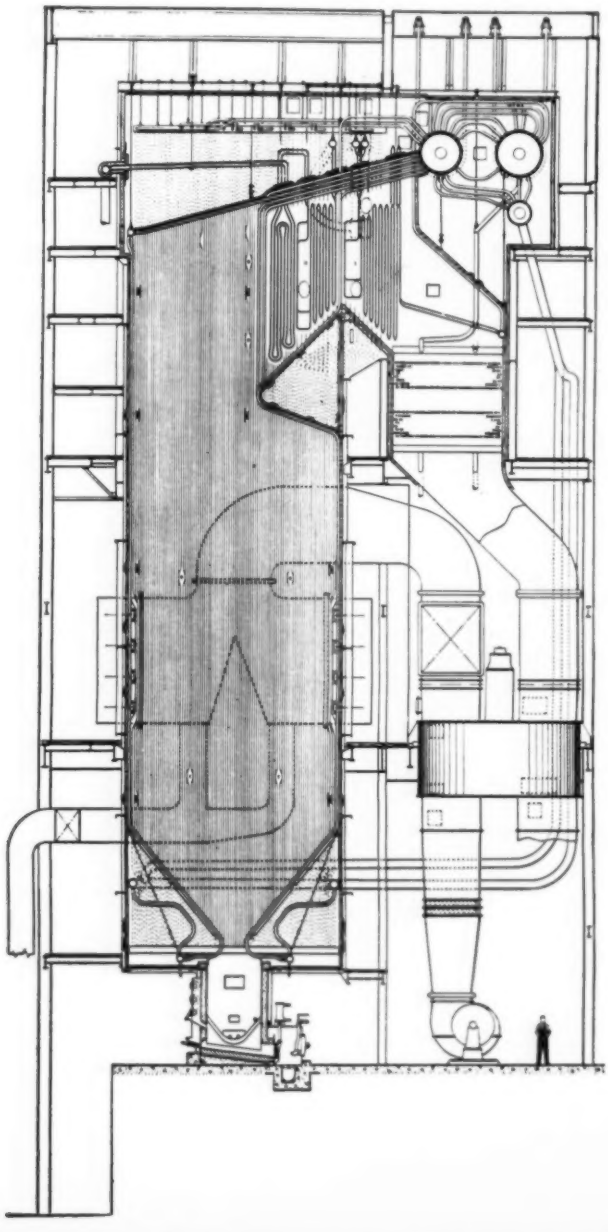
Power Program at A.S.M.E. Annual Meeting ▶

Notes on Underground Gasification ▶

Recent C-E Steam Generating Units for Utilities

HAWTHORN STEAM ELECTRIC STATION

KANSAS CITY POWER & LIGHT COMPANY



THE C-E Unit illustrated here is one of two duplicate units now in process of fabrication for the new Hawthorn Steam Electric Station of the Kansas City Power & Light Company.

Each unit is designed to produce, at maximum continuous rating, 625,000 lb of steam per hr at 1335 psi and 955 F.

These units are of the radiant type with 3-stage superheaters followed by finned tube economizer surface and regenerative type air heaters.

The furnaces are completely water cooled using part plain tube and part finned tube surface. They are of the basket-bottom type discharging to sluicing hoppers.

Pulverized coal firing is employed using bowl mills and vertically-adjustable, tangential burners. Provision is also made for the use of natural gas as an alternate fuel.

B-354

C-E

Combustion Engineering–Superheater, Inc.

A Merger of COMBUSTION ENGINEERING COMPANY, INC. and THE SUPERHEATER COMPANY

200 MADISON AVENUE, NEW YORK 16, N. Y.

Editorials

Uses for Fly Ash

The symposium on Fly Ash Disposal during the A.S.M.E. Annual Meeting revealed many promising uses for this by-product of pulverized coal firing. That so much has already been accomplished toward establishing substantial markets for fly ash as a filler in bitumastic road building, in making cinder blocks and as a partial substitute for portland cement in concrete construction was a revelation to many present, particularly the fact that it is being employed to the extent of 140,000 tons by the U. S. Engineer Corps in construction of the Hungry Horse Dam in Montana—the fourth largest dam in the world.

Other applications, such as an insulating cement, a soil stabilizer and for core use in the foundry trade, appear to have merit, but it is the bulk demand that is most attractive from the standpoint of offsetting much of the expense of installing fly-ash recovery equipment. In this connection one of the authors observed that a blend of 90 per cent portland cement and 10 per cent fly ash, if substituted for the portland cement used for concrete in the eastern half of the United States during 1948, would have consumed all the fly ash produced in that year.

Cost of Coal Storage

Although the decision of John L. Lewis to permit the miners to continue working on a three-day week will probably avert a widespread fuel shortage during the next few months, it nevertheless will further reduce the stocks in the hands of consumers. These stocks, which had attained record size early last summer, were not reduced as rapidly as Mr. Lewis had anticipated, due to the heavy inroads of oil and natural gas, but his latest action is undoubtedly aimed at depletion to a point where he will have the upper hand in further bargaining, at the same time avoiding an emergency situation such as might warrant government intervention.

However, there is another aspect of the necessity for building up consumer stock piles as an insurance against the effects of recurring stoppages—one that is probably not fully appreciated by the general public. It is the idle capital thus tied up, together with the fixed charges involved, which must enter into the cost of generating electricity for public use or power for industrial production.

Stocks in the hands of public utilities at the beginning of dislocation in coal supply some months ago amounted to approximately thirty million tons, according to the Federal Power Commission. It would be difficult to arrive at an estimate of the average price of this coal, but if a conservative figure of six dollars a ton be assumed, the total cost would amount to about 180 million dollars. Not only does this represent unproductive tied-up investment, with its carrying charges, but there is the very appreciable cost of putting the additional coal into and out of storage.

The foregoing figures concern only the electric utilities whose consumption of coal is greatly exceeded by industrial plants of all kinds. While only the bigger industrials have facilities for extensive coal storage, the total involved must be very great. At least half and probably two-thirds of the total could be avoided by an assured steady supply of coal.

Can You Profit by Modernization?

One of the real strengths of the free enterprise system of American industry lies in the thousands of productive plants—large and small—scattered throughout the nation. How these individual units meet the challenge of technological change frequently affects employment stability in their respective communities and influences the rate of economic gain that may be achieved. In this production-conscious land attention is most commonly centered upon factors that have obvious and readily observable values in terms of increased production, reduced unit cost, or improved quality. Too often neglected in the drive for greater productivity and higher output per man-hour are the plant services upon which industrial operation is dependent. Unless there is some emergency which is the cause of a major plant shutdown, these important adjuncts to production receive relatively little attention from top management.

That power-plant equipment is subject to technological change and obsolescence should be apparent to all upon a little reflection. Knowing how these factors operate with respect to production equipment, isn't it probable that modernization of plant services may provide an attractive return upon the necessary investment? If your plant is one that has spent a large sum in minimizing manual labor in materials handling, has similar consideration been given to the transport of coal and ashes? Have you installed the latest electronic controls on your productive machinery while your boiler plant continues to operate by manual control and uncertain human adjustments? Do you realize that outmoded and inefficient boilers can continue to generate your steam at the costly price of excessive fuel bills? How many of these factors have you considered?

An article in this issue tells how the progressive management of one textile plant modernized facilities for steam generation. Undoubtedly conditions in your plant are different, but it is no less true that you, too, can profit from modernization. Why not give it serious consideration?

Steam Plant at Susquehanna Mills Designed for Rapid Load Changes

STEAM generation is an important factor in textile plant operation and is so recognized by progressive management. No matter how changes in fabric and garment style may affect productive equipment, the power plant must be operated and remains a significant part of manufacturing cost. In many mills the annual expenditure for power and steam is equal to or greater than the fair profit on the business of an average year. When to this cost is added the serious consequences resulting from even temporary failure of the power or steam supply, the importance of efficient and thoroughly reliable power plant equipment becomes more apparent. In a field as highly competitive as the textile industry this is a factor that cannot be overlooked.

Here is an interesting case study of boiler plant modernization in the textile industry. It is indicative of what an alert management can do in collaboration with an experienced firm of consulting engineers. The article outlines studies made preparatory to equipment selection, decribes the completed plant and mentions results achieved from operation over a period of nearly two years with rapid load changes.

Let us retrace the thinking and planning that went into the modernization of the steam generating facilities of Susquehanna Mills, Inc. Here is a company whose origin can be traced back to the highly developed German textile industry of the latter part of the nineteenth century. When tariff barriers made it advantageous to manufacture goods in America, Julius Schniewind emigrated to this country and in 1896 established a silk mill in Sunbury, located at the junction of the North and West branches of the Susquehanna River in central Pennsylvania. Under the terms of the establishment of the new industry, it was agreed to construct a $200,000 mill and to hire 200 persons within two years in return for title to the plant site and certain tax concessions.

Exterior view of boiler house

Early operations consisted solely of silk weaving and were carried on in the familiar saw-tooth type of industrial buildings. Steam was required only for heating and was provided by small hand-fired boilers. As production expanded the mill was enlarged, and in 1923, four horizontal return-tubular boilers having a rating of 150 boiler horsepower each were installed. These, too, were hand fired and had flat dumping grates, both coal and ashes being handled manually.

Meanwhile the silk industry had been undergoing a marked change, and with the increasing importance of newly developed synthetic fibers and the manufacture of worsted gabardines the character of the plant operations changed. By 1941 it was found advantageous to incorporate dyeing and finishing facilities with the other plant productive processes. Obviously, this greatly increased the demand for process steam, and in 1944 it became apparent that steps had to be taken to augment the steam supply. Though the plant remains primarily a diversified weaving industry which produces woolens, worsteds, upholsteries, and broadsilks from such fibers as plastic yarn, rayon, silk, and nylon, dyeing and finishing are assuming ever increasing importance.

Steam is required for both heating and process use. Over a 24-hr period the heating load remains fairly constant or changes in a manner that can be predicted from weather conditions. On the other hand, the process load is extremely variable, being subjected to wide swings and sudden fluctuations. This can be more readily understood by knowing that there are many batch processes in dyeing and finishing which require relatively large quantities of steam and hot water for short periods, followed by longer intervals of relatively constant steam requirements of greatly diminished quantity. Studies made in 1944 by the Franklin Engineering Corporation gave graphical evidence of this condition, as shown in the curves of steam consumption in the dye house and throughout the plant for a typical day.

The same engineering study revealed that the four horizontal return-tubular boilers installed in 1923 were still capable of producing more than their rated capacity of steam in 1944. However, plant load had grown beyond the limits of safe and dependable operation of the boilers, and decisions had to be made to obtain increased steam capacity.

One alternative was to expand the existing boiler room, substantially duplicating much of the installed equipment; but consideration of the many improvements in the practice of steam generation pointed to the advisability of replacing fire-tube boilers with water-tube boilers and substituting mechanical coal and ash handling for the manual method then in use. In addition, modern combustion control afforded a means of operation to cope with rapid fluctuations in steam load.

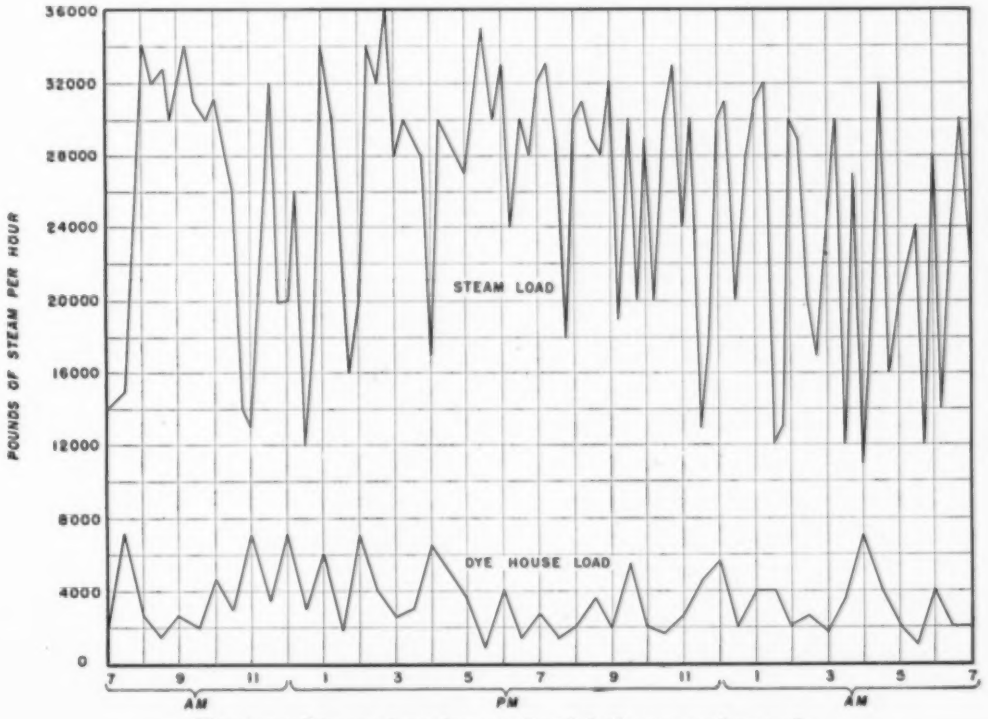


Chart used in engineering study of daily steam demand

The management, in cooperation with its consulting engineers, accordingly decided to proceed with the design and construction of a new steam plant. It was agreed that water-tube boilers, stoker firing, mechanical coal and ash handling, and automatic combustion control would be incorporated in the design.

There were several determining factors in the selection of a boiler, primary among which was capability to produce steam at constant pressure under widely fluctuating loads. It was felt that a two-drum design incorporating a completely refractory setting without water walls would serve these needs. To minimize setting maintenance costs, a conservative heat release of less than 25,000 Btu per cu ft per hr was specified. The large furnace volume serves to keep flue gas velocities to a low value and to lessen fly-ash erosion and emission. The geo-

graphical location of Sunbury made anthracite the most economical fuel and led to the decision to install a traveling grate stoker of the Coxe type.

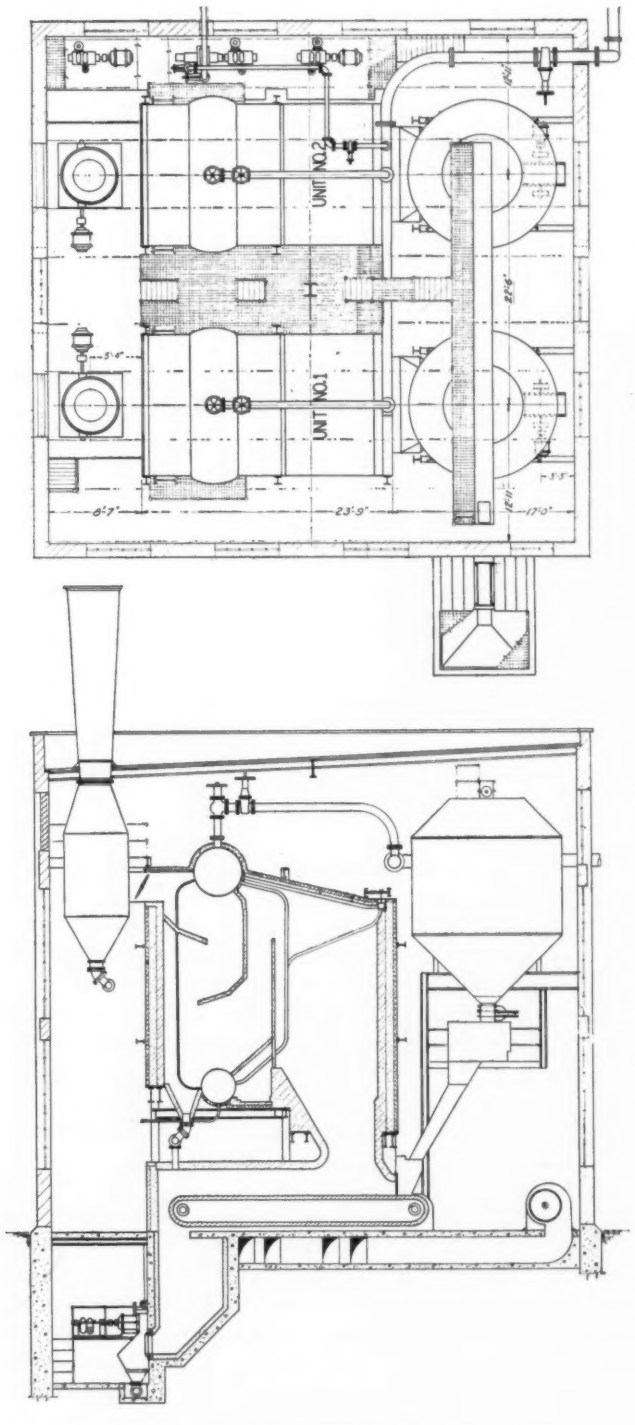
The new steam plant is located in a recently constructed brick and steel building adjacent to the main mill. The general arrangement of equipment in this structure, which is 52 ft long, 51 ft wide and 45 ft high, is shown in the plan and elevation views. An unusual feature is that the equipment is so well insulated that unit heaters are installed for the comfort of the operators during the heating season.

There are two Combustion Engineering Type VU steam generating units having a normal rating of 35,000 lb of steam per hour each and a guaranteed efficiency of 74.1 per cent. Four-hour peak capacity is 40,000 lb of steam per hour. Saturated steam is generated at 135 psig, and provision is made for a future interbank superheater designed to deliver 50 deg F superheat. Design pressure is 250 psig. The all-refractory setting is steel encased.

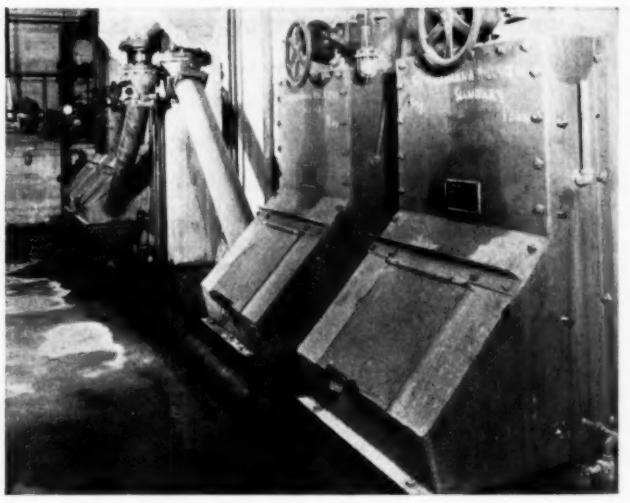
Firing is by means of C-E traveling grate stokers. The fuel is a mixture of Nos. 2, 3 and 4 buckwheat anthracite having the following ultimate analysis (on a dry basis):

Ash	24.2%
Sulfur	0.6%
Fixed Carbon	68.1%
Hydrogen	3.1%
Nitrogen	1.0%
Oxygen	3.0%
Heating value, Btu per lb	11,205

Boiler auxiliaries include Warren boiler feed pumps, Bayer soot blowers, Copes feedwater regulators and Hagan combustion control. The draft system for each boiler is composed of a Clarage motor-driven, forced-draft fan and a Prat-Daniel Thermix stack and induced-draft fan. The forced-draft fans each have a capacity of 15,000 cfm at 4-in. static pressure and 100 F at the fan outlet. Design conditions for the induced-draft fans are 30,000 cfm against 1.2-in. static pressure and a flue gas temperature of 590 F.



Plan and elevation of boiler plant

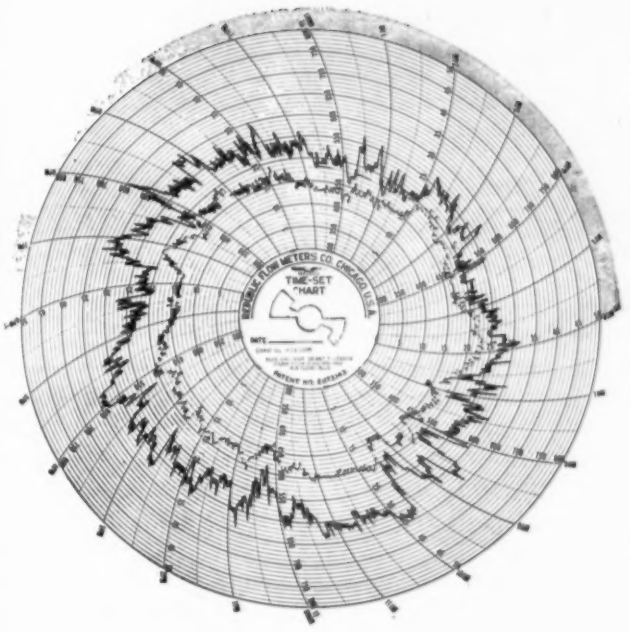


View of ash-disposal system

Coal may be received by rail or by truck and is handled by a Beaumont Birch elevator and conveyors to individual overhead steel bunkers having a capacity of 50 tons for each boiler. Flow of coal is by gravity through coal scales to the stoker hoppers. All ashes are disposed of hydraulically by a United Conveyor Corporation system which discharges them for fill to reclaim land in an undeveloped section of the mill property.

Dearborn chemical treatment is applied internally to the boiler drum in batches. The water is of good quality, and no troubles attributable to it have been experienced. Continuous blowdown is used.

Designing of the new plant was carried out by Franklin Engineering Corporation, S. E. Friedeberg, vice president,



Operation chart showing variable steam demand as well as flue gas temperature

who also supervised construction, assisted by Harold Kerstetter, plant engineer of Susquehanna Mills, Inc. The use of plant personnel and local contractors in this phase of the work resulted in substantial savings in the overall cost of the project.

Operating Results

The new steam plant went into operation early in January of 1948. Steam requirements to date have been such that the entire load can be handled by one steam generating unit. The other is held in reserve as standby, the units being alternated in periodic lengths of service.

From the chart of daily operation herein reproduced it will be noted that the rapid steam load conditions for which the plant was designed have been encountered. Not only have the boilers proved responsive to the wide load fluctuations shown, but they have also accomplished this while maintaining constant steam pressure.

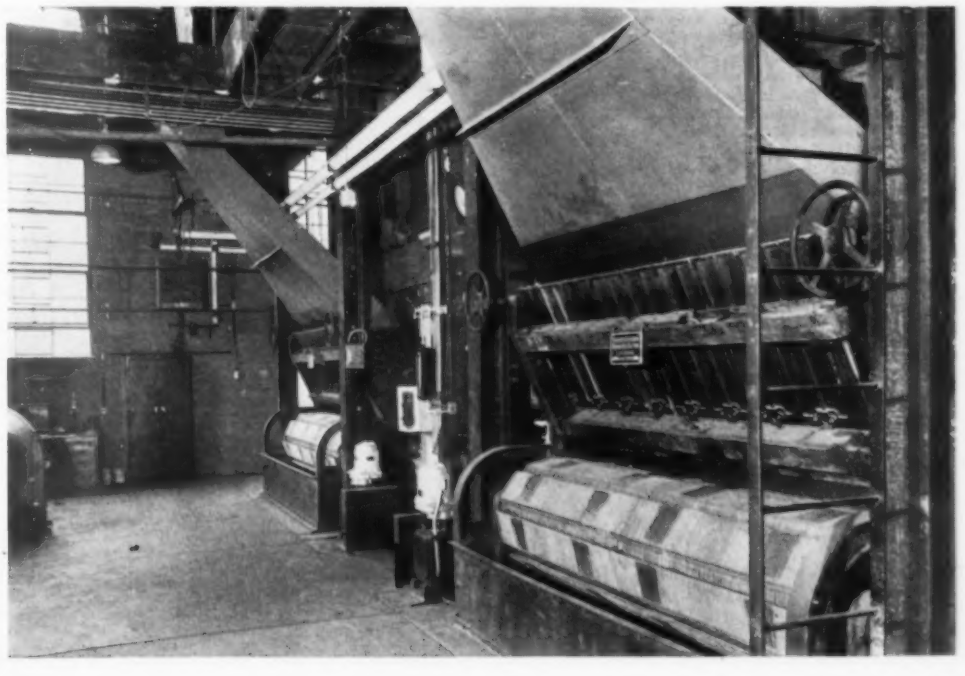
Although anthracite fuel costs have risen approximately 75 per cent and labor costs, 25 to 30 per cent in the five-year period dating from 1944, operating costs of the new boiler plant have increased only 25 per cent.

Since their installation the boilers have required no furnace maintenance. In addition to burning the usual fuel, the traveling grate stokers have also maintained full boiler ratings with the combustion of anthracite fines reclaimed from the Susquehanna River and its tributaries. The supply of this inexpensive fuel is decreasing as a result of efforts to curb stream pollution.

The entire personnel of the new boiler plant consists of five operators, whereas the old boiler plant required thirteen men. This has made available eight persons who have been assigned to other duties in the mill. The five operators, who have greatly improved working conditions together with far less physical work, obtain and keep records of boiler plant operation which are of value to management in determining accurate steam costs. These men also maintain a constant check on all equipment which reduces maintenance charges and relieves the regular mill maintenance mechanics from serving the boiler plant.

Conclusions

The new steam plant of Susquehanna Mills, Inc., exemplifies what can be done to modernize plant services by the cooperative efforts of progressive management and competent consulting engineers. A reliable and efficient steam generating installation has been designed and placed in service, and substantial savings in labor and fuel costs have been achieved. At the same time working conditions have been improved, and dependable steam generation to meet rapid load changes has become a reality.



Interior view of boiler plant, showing 180-sq ft traveling grate stoker of the Coxe type

Come to POWELL for ALL your Valves

Fig. 11313 W.E.—Class 1500-pound Cast Steel Pressure Seal Gate Valve. Has venturied ports, welding ends and special by-pass. Bevel gear operated.

There are obvious disadvantages in buying flow control equipment from several different sources. Then why get your bronze or iron valves from one place, your steel valves from another, and possibly corrosion-resisting valves from several others, when Powell *makes them all**?

This is an age of specialization; and whereas various manufacturers are emphasizing valves that meet certain flow control requirements, Powell specializes in making valves to meet *all* the demands of every branch of Industry. And there's only one standard of quality at Powell—to make the right valve to suit the service, and to make it the best.

Plants representing every branch of Industry have found that it pays to make Powell—and *only* Powell—responsible for the performance of all their flow control equipment. So why not come to Powell for all *your* valve requirements?

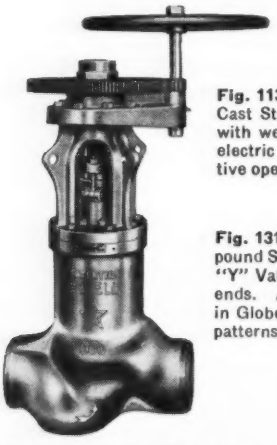


Fig. 19084 W. E.—Class 900-pound Cast Steel Pressure Seal Globe Non-Return Valve with welding ends and spur gear operation. Its improved streamline design reduces pressure drop and turbulence to the minimum.

Fig. 11323 W. E.—Class 1500-pound Cast Steel Pressure Seal Gate Valve with welding ends. Has top-mounted electric motor operator for quick positive opening and closing.

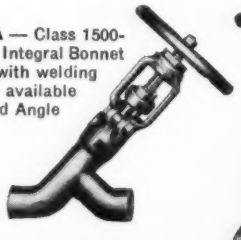


Fig. 1314-A — Class 1500-pound Steel Integral Bonnet "Y" Valve with welding ends. Also available in Globe and Angle patterns.

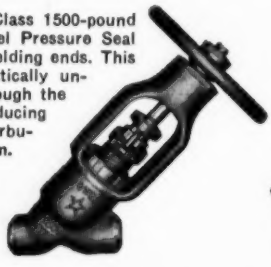


Fig. 11331 W. E.—Class 1500-pound small size Cast Steel Pressure Seal Globe Valve with welding ends. This design permits practically unobstructed flow through the valve body, thus reducing pressure drop and turbulence to the minimum.

Fig. 3031 W. E.—Class 300-pound Cast Steel O. S. & Y. Globe Valve with welding ends.

Fig. 241—Large 125-pound Iron Body Bronze Mounted O. S. & Y. Globe Valve.

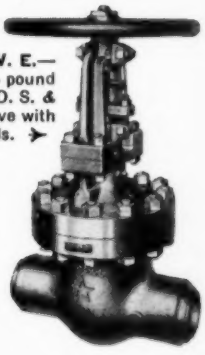


Fig. 9003 W. E.—Class 900-pound Cast Steel O. S. & Y. Gate Valve with welding ends. ➤

Fig. 1708 — 200-pound Bronze Globe Valve with renewable stainless steel seat and regrindable, renewable "Powellium" nickel-bronze disc.

Fig. 375 — 200-pound Bronze Gate Valve with renewable wear-resisting "Powellium" nickel-bronze disc. ➤

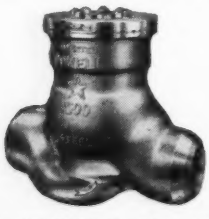


Fig. 11365 W. E.—Class 1500-pound Cast Steel Pressure Seal, Piston-Guided, Horizontal Lift Check Valve with welding ends.

Fig. 1793—Large 125-pound Iron Body Bronze Mounted O. S. & Y. Gate Valve.

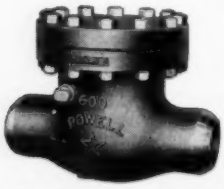


Fig. 6061 W. E.—Class 600-pound Cast Steel Swing Check Valve with welding ends.

*The Complete Powell Line includes Globe, Angle, Gate, Check, Relief and Flush Bottom Tank Valves in Bronze, Iron, Steel and a wide range of Corrosion-Resisting metals and alloys.

Ask your nearest Distributor—or write direct

The Wm. Powell Co., Cincinnati 22, Ohio

DISTRIBUTORS AND STOCKS IN ALL PRINCIPAL CITIES

POWELL VALVES

Varied Power Program at A.S.M.E. Annual Meeting

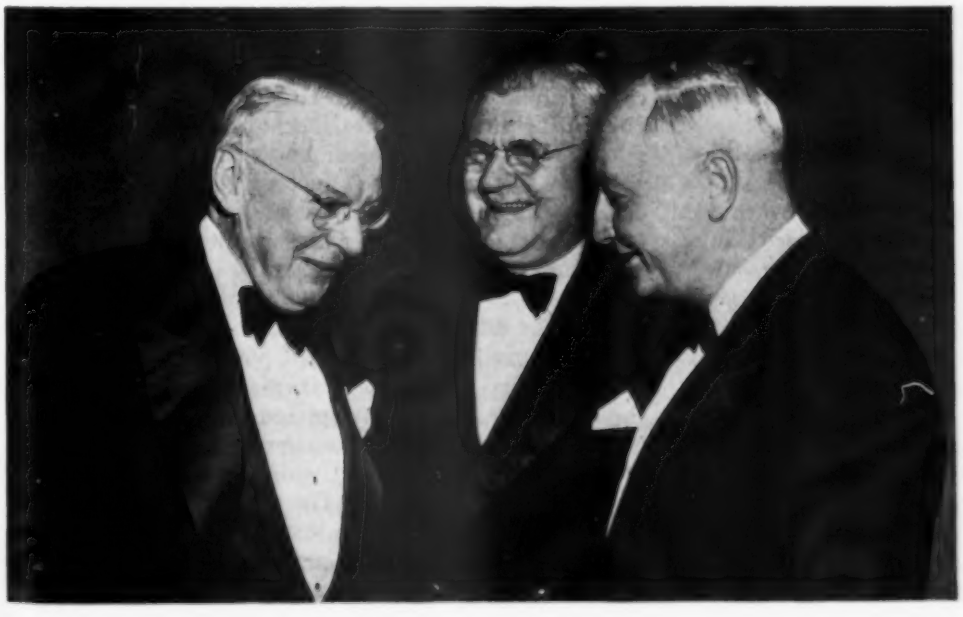
THE 70th Annual Meeting of the American Society of Mechanical Engineers, held at the Hotel Statler, New York, N. Y., November 27 to December 2, featured an extremely varied program of technical and general interest sessions. There were 74 technical sessions and more than 300 engineering papers in such fields as hydraulics, industrial instruments, applied mechanics, rubber and plastics, aviation, materials handling, heat transfer, power, fuels, wood industries, petroleum, machine design and textiles.

At the first Roy V. Wright Memorial Lecture, Chief Justice Arthur T. Vanderbilt of the New Jersey Supreme Court delivered an address entitled "Standards for Citizenship." Not only are such official duties as voting and jury duty important, but the engineer as a citizen also has the responsibility to know and understand public problems so as to mold intelligent public opinion. Justice Vanderbilt questioned the wisdom of allowing patriotism to be merely a wartime virtue and urged that more interest be taken in government activities in peacetime.

Some of the outstanding general interest meetings were sponsored by the Management Division of the Society. These included a session on the obligations implied by trusteeship, the obligations of management to create a better industrial life in which Harry Read of C. I. O. presented the views of labor, and Fred C. Fischer of R. H. Macy & Co., those of management; and the obligation of management to control cost and to create quality. At the management luncheon the Gantt Medal for 1949 was presented to Arthur C. Spurr, president of the Monongahela Power Company, in recognition of his leadership in revitalizing the social and economic life of the area of his influence. Frederick S. Blackall, Jr., delivered the Henry R. Towne Lecture and urged that management take greater political action as insurance for the industrial climate of the future.

Fred L. Dornbrook of the Wisconsin Electric Power Co. receives the A.S.M.E. Medal from President Todd for "Outstanding engineering in the research, design and operation of pulverized fuel equipment."

There were a number of papers devoted to the adjustment of the young engineer in his first industrial position. Guy Kleis of Westinghouse Electric Corporation and J. S. Crout of Battelle Memorial Institute discussed "Orientation and Training of the Young Engineer in Industry," and K. B. McEachron, Jr., of General Electric Company explained some of the problems in "Integrating the Young Engineer into His Community." At a symposium sponsored by the Junior Committee, M. M. Boring of General Electric Company presented views



Left to right: James D. Cunningham, incoming president; C. E. Davies, secretary of the Society; and James M. Todd, outgoing president

on opportunities afforded by the large corporation for young engineers, while Crosby Field of the Flakice Corporation painted a contrasting picture of the future of young engineers in small companies.

Two addresses were delivered at the Annual Dinner and Honors Night. H. J. Gough, president of the Institution of Mechanical Engineers, London, England, asked for continued cooperation and a closer relationship between the mechanical engineers of the two English-speaking nations. President James Todd of the A.S.M.E. proposed that American engineers provide for the rest of the world the necessary inspiration to struggle toward a higher level of civilization. He urged that engineering developments be used for peace instead of destruction and that the free-enterprise system be strengthened in the United States. James D. Cunningham, president of Republic Flow Meters Co., was introduced as president-elect of A.S.M.E.

Selection of Steam Conditions

Reasons for selecting a turbine of 75,000-kw capability and steam conditions of 1450 psig, 1050 F were analyzed by **R. C. Dannettel** and **G. S. Harris** of the Consolidated Gas Electric Light and Power Company of Baltimore in a paper entitled "Selection of Steam Conditions for No. 4 Unit at Riverside Generating Station." Consideration was given to the following sizes of units and operating conditions:

66,000-kw capability, 850 psig, 900 F

75,000-kw capability, 1250 psig, 950 F with reheat to 950 F

75,000-kw capability, 1450 psig, 1000 F with reheat to 1000 F

75,000-kw capability, 1450 psig, 1050 F

Since the company had in operation four 60,000-kw 850 psig turbine-generators, their performance and steam conditions were used as a measuring stick. As a unit with 75,000-kw maximum capability could be accommodated by the system, the study centered around a "Preferred Standard" 60,000-kw unit with 66,000-kw capability for 850-psig, 900-F steam and three alternate arrangements embodying 60,000-kw nominally rated, 75,000-kw maximum capability units for both straight-through condensing and reheat cycles.

Construction estimates were prepared and disclosed a spread of less than two per cent in the cost per kilowatt of capability. The 1250-psig, 950/950-F unit showed the lowest installation cost per kilowatt of capability with the 1450-psig, 1050-F straight condensing unit a very close second. The 1450-psig, 1000/1000-F design showed the highest installation cost. A comparison of fixed charges resulted in the same order of units.

With respect to heat rates, the 1450-psig, 1000/1000-F design was found to be about $12^1/_2$ per cent better than the 850-psig, 900-F unit. Annual generation was arbitrarily set at 6000 hr of operation at 66,000 kw for all units. A curve was plotted using the cost of coal in dollars per ton as abscissas and the cost to "own and operate" as ordinates. The latter was defined as the sum of fixed charges and fuel costs, and the fixed charges of the 75,000-kw units were reduced proportionately to 66,000 kw for comparative purposes. With coal at $8.50 per ton and a cost to "own and operate" of approximately $3,000,000 per year, there was a spread of about $180,000 or about 6 per cent. The highest cost was for the 850-psig, 900-F unit; the lowest cost was for the 75,000-kw, 1450-psig, 1000/1000-F unit. To own and operate the 75,000-kw, 1450-psig, 1050-F straight condensing unit the annual cost was computed to be about $24,000 above that of the 1000-F reheat unit.

Considering the accuracy of estimating, it appeared reasonable to put the 1450-psig, 1050-F straight condensing unit on the same basis as the 1450-psig, 1000/1000-F unit insofar as total expense for fuel and fixed charges was concerned. Final selection thus rested on judgment of availability, reliability and maintenance.

Disadvantages ascribed to the reheat unit included less reliability because of its more complicated controls, less responsiveness to load changes, possible increased maintenance due to multiplicity of piping and controls, the requirement of two superheaters and their controls, uncertain thermal gains from reheat during light-load operation, and waste of steam and fuel sometimes necessary to protect the reheater from overheating. The authors concluded with the following statement:

"In comparison with reheat units, the 1450-psig, 1050-F straight-condensing unit should be simpler to install and operate; with less controls should be more reliable and available; should be more adaptable during system disturbances and for frequency regulation; and, considering maintenance and probable light load operation, should be more economical in total dollar costs to the company during the life of the unit."

Investment Costs of Reheat vs. Non-Reheat

Analysis of the differences in investment costs of the various elements of a steam power plant, as affected by choice between the reheat or non-reheat cycles for 1450 psig, single-boiler, single-turbine units of about 100,000-kw capability, was contained in a paper by **R. P. Moore** of the Buffalo Niagara Electric Corporation.

Because of improved cycle efficiency the boiler plant, excepting the boiler itself, will generally cost less with reheat; although, in figuring differences in cost of equipment for the two cycles, where standard sizes exist, it may not be possible to use a smaller size.

Certain other parts of the plant, such as high-pressure steam piping, feed pumps and piping, condenser and circulating pumps, intakes, discharge flumes and screens vary more in size than efficiency would indicate.

Those parts which are affected little, if any, by cycle efficiency include land, turbine hall, electrical structures and equipment, feedwater treatment, evaporators, and metering equipment.

The turbine, boiler and reheat piping represent added cost for the reheat cycle.

On the basis that the cost of power plant equipment does not vary directly with its size, but more nearly as the factor 0.7, the author applied this to cost data for a number of non-reheat units under construction or recently completed, and arrived at certain credits and debits for the two cycles. The net result was a credit of $2.16 per kw for reheat against a debit of $3.88 per kw, making a net additional charge of $1.72 per kw for the reheat cycle.

This figure must be balanced against the operating saving through improved efficiency, which will vary with the price of fuel.

Economics of Reheat

A paper by **R. W. Hartwell** and **H. A. Wagner** of The Detroit Edison Company entitled "Some Factors Influencing the Economics of Reheat Installations" dealt with certain of the economic factors that must be considered in choosing between (1) a battery boiler system and a unit boiler-turbine system and (2) a reheat and a non-reheat installation The availability of capacity, the result of different maintenance schedules on availability, and the assignment of capital charges resulting from the difference in average available capacity were given special consideration

Four plant designs were selected for study. Each has an installed capacity of 400,000 kw in four 100,000-kw tandem-compound, double-flow, 1800-rpm turbine-generators. Plant A, the battery boiler system, consists of five interconnected boilers; Plant B has four boilers, each connected directly to its own turbine; Plant C has four boilers, one for each turbine, which are connected by a crossover; Plant D is the unit system as for Plant B, but provided with reheat.

Plants A, B and C were assigned 1300-psig, 950-F throttle conditions. For Plant D an effort was made to choose conditions high enough to favor reheat and yet be somewhat comparable with the non-reheat condition; 1450-psig, 1000 F–1000 F were selected.

The boilers for Plants A and B are each rated at 970,000 lb of steam per hr which represents an excess steam generating capacity of ten per cent over maximum requirements for one 100,000-kw turbine-generator. One spare boiler was provided for Plant A, where all units supply steam to a common header. In Plant C sufficient crossover piping is provided so that any of the four boilers can supply steam to any of the turbines, and the boilers have a capacity of 1,100,000 lb per hr so that any three can generate sufficient steam to carry rated load on all of the four turbine-generators. The reheat boilers in Plant D are comparable to Plant B in that the units are entirely separate and 10 per cent excess steam generating capacity is provided.

Pumps and heaters have similar arrangements for all plants, except that five feedwater heaters are provided in Plants A, B and C, whereas there are six heaters in Plant D.

Curves were plotted to compare the plants from the standpoint of total operating costs. These curves show the effect of including capacity charges, of varying the annual plant factor, of shortening maintenance time on boilers and turbine-generators, and of varying the coal costs. Where capacity costs are included, the plant with the greatest availability is favored. With no capacity charges, the unit system without crossover, Plant B, has a significant advantage over the unit system with a crossover installation, Plant C.

As the annual plant factor for a comparatively low availability installation is increased, the amount of generation assigned to low economy machines must be increased. Reducing the number of days the boilers and turbines are out of service for general maintenance improves the savings rate of all unit system plants. A change in coal cost has a pronounced effect upon the potential savings of a reheat plant.

With respect to reheat, the authors made the following statement: "The reheat installation appears favorable economically in all cases, although if 100 per cent capacity charges are assigned, and annual plant factors of 60 per cent or lower are used, the savings in favor of reheat are considerably reduced. In this case, any extra complexity in operation, possible reduction in coal cost, or long-time partial load operation at less than 75 per cent name-plate rating, would militate against a reheat installation."

Messrs. Hartwell and Wagner emphasized that their study was only a partial one which is to be followed by other investigations of such factors as throttle conditions, sizes and types of turbine-generators, and other design characteristics. Some of their conclusions on this basis indicated that assignment of fixed charges, where justified by minimum reserve capacity, may have a pronounced effect on the cost of operation of the four types of plants considered. Several significant influences upon annual operating cost are variation in annual plant factor, single or double shift maintenance, and increase in coal costs.

Discussion

Among the points covered in the discussion of the three papers concerning the relative economics of reheat and non-reheat installations were those pertaining to the effect of crossovers and boiler interconnection upon plant availability, methods of rating boilers, relation of power plant design to reserves and the electric system as a whole, and economic returns to be gained from reheat.

There was not complete agreement concerning the effect of interconnecting boilers upon plant availability. The comparison by Messrs. Hartnell and Wagner between the unit system without crossover and a unit system with crossover or a battery boiler system indicated that the availability of the latter was slightly greater than with the independent unit system. On the other hand, some engineers contended that there is less outage with plants having no crossovers because of the simplification of the piping system.

Problems of evaluating boiler output were mentioned in connection with the use of reheat. It was noted that outputs in pounds of steam per hour may be misleading, particularly if reheat and non-reheat boilers are compared. A system of boiler evaluation incorporating heat input or heat output or (with unit boiler-turbine plants) megawatts was proposed.

There was considerable emphasis upon the importance of power plant design in relation to the electric system as a whole, especially where design affects reserves and system reliability. Heretofore, reserve requirements have not always received the attention that they deserve from the designer. The application of the theory of probability in setting up reserves was advocated, and the effect of crossovers and unit boiler-turbine plants in allocating reserves was mentioned.

It was pointed out that the economic gains from reheat may be wiped out if such installations lack high availability. On the other hand, all three of the economic comparisons indicated that fuel savings from reheat at

least balanced fixed charges on the additional investment beyond that for a non-reheat, unit-boiler-turbine plant. The return from reheat should be considered on the basis of return to the stockholder, one discusser advocating that a greater return than fixed charges should be obtained.

Regenerative Steam-Cycle Heat Rates at High Steam Temperatures

"Possibilities of the Regenerative Steam Cycle at Temperatures Up to 1600 F" was the title of a paper by **P. H. Knowlton** of the General Electric Co. and **R. W. Hartwell** of The Detroit Edison Co. They took into consideration theoretical and practical possibilities of higher temperatures and made an economic evaluation of heat-rate differences.

In considering the merits of one steam condition over another, it is desirable to evaluate the anticipated differences in heat rates. Basis factors for such an evaluation include the cost of fuel, load characteristics, auxiliary power requirements, boiler efficiency, turbine heat rates and annual fixed charges on plant investment.

A table was developed to indicate additional justified investments per 100,000 kw of capacity in comparison to the cost of a 1250-psia, 950-F plant. A fuel cost ranging from 10 to 35 cents per million Btu was covered in the evaluation, which also incorporated a plant load factor varying from 50 to 80 per cent. In making up the table for evaluating the economics of heat rate differences it was assumed that natural-circulation boilers would be used for throttle pressures up to and including 2000 psia; for 2500 psia estimates were based on a steamotive cycle boiler with recirculating pumps capable of handling 130 per cent of steam flow; and for 3000-psia throttle pressure a once-through forced-circulation boiler was the basis of the estimate used in the evaluation. Efficiencies for pulverized-coal-fired boilers with feedwater temperatures approaching 600 F and exit gas temperatures of about 300 F were assumed to vary between 87.7 and 88.8 per cent. An annual fixed charge rate of 10 per cent was assumed in computing the justified additional investments that would be required for these higher steam conditions.

In their conclusions Messrs. Knowlton and Hartwell noted that the practical regenerative steam cycle shows less improvement with increasing pressure, and more improvement with increasing temperature, than the theoretical cycle. This is due to the fact that the practical turbine loses in efficiency with increasing pressure, and gains in efficiency with increasing temperatures, while the theoretical turbine is always assumed to be 100 per cent efficient.

The trends noted are not at all new; the only novelty is their extrapolation to show what economies may be expected at temperatures of 1600 F and pressures up to 3000 psi.

Actual use of steam temperatures above the present upper limit of 1050 F will depend on the development of suitable materials for the higher temperatures, and on the design of acceptable equipment, particularly boilers and turbines, at a cost in line with realizable thermal gains.

Discussion

Several engineers commented on the value of the paper by Messrs. Knowlton and Hartwell because of its usefulness in making future studies of the economic advantages to be derived from higher steam temperatures and pressures. The results as presented are sufficiently flexible so that they may be adjusted for variations in annual plant factor, fuel costs per million Btu, and annual fixed charges.

In connection with higher steam temperatures, it was suggested that there may be some advantage in using materials for superheaters and reheaters having shorter life than the remainder of the steam generating unit, but being adaptable to easy replacements. The possibility of modifying boiler codes to cover dual standards of stress limitations for different periods of life at elevated temperatures was mentioned. Experiences in the oil refining industry might be reviewed to good advantage in this matter.

Steps beyond the present temperature limit of 1050 F must be taken gradually. Scarcity of alloy materials may make necessary the search for new high-temperature-resisting materials which can be found in greater abundance. It was anticipated that high reliability of power plant equipment would be maintained for higher steam conditions.

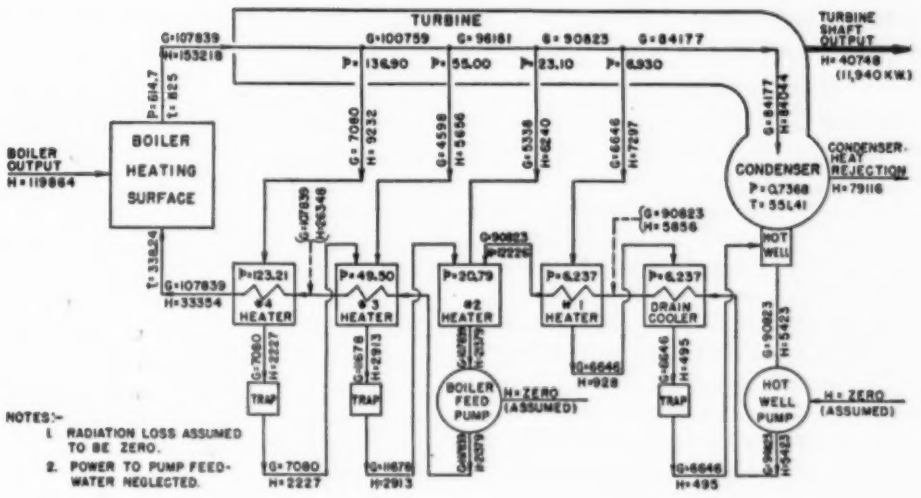
Some comments were made concerning the accuracy and limitations of steam tables. It was pointed out that the present upper limit of direct measurement of enthalpy is 1000 F and that values above that temperature are obtained by extrapolation. However, it was felt that the error from the use of present steam tables up to temperatures of 1600 F would be on the order of 5 per cent which would be within the limitations of other data now available for the study of extreme temperature conditions.

The fact that as steam temperatures were increased reheat could continue to gain an additional 5 per cent in thermal efficiency was emphasized. Several engineers expressed the hope that the data presented in this paper will stimulate additional interest in the solution of the problems of developing materials for higher steam conditions.

Steam Plant Losses from the Entropy Balance Diagram

"The Evaluation of Steam Power Plant Losses by Means of the Entropy Balance Diagram" was the title of a paper presented by **Allen Keller** of the General Electric Co. Since entropy is a measure of unavailability of energy from the standpoint of the complete power plant, an entropy balance diagram may be used to evaluate losses and to obtain quick answers to the effect of design changes.

An entropy balance diagram is a chart similar to a heat balance diagram, on which is represented the flow of entropy throughout the entire steam cycle of a power plant. One important difference is that in the heat balance diagram enthalpy is added or subtracted from the thermodynamic medium only in the boiler, turbine, feedwater pumps and condenser (at other points it is merely transferred, as from steam to water in a feedwater heater), while in an entropy balance diagram the



Conventional heat-balance diagram for 11,500-kw Preferred Standards turbine-generator operating at rated load.

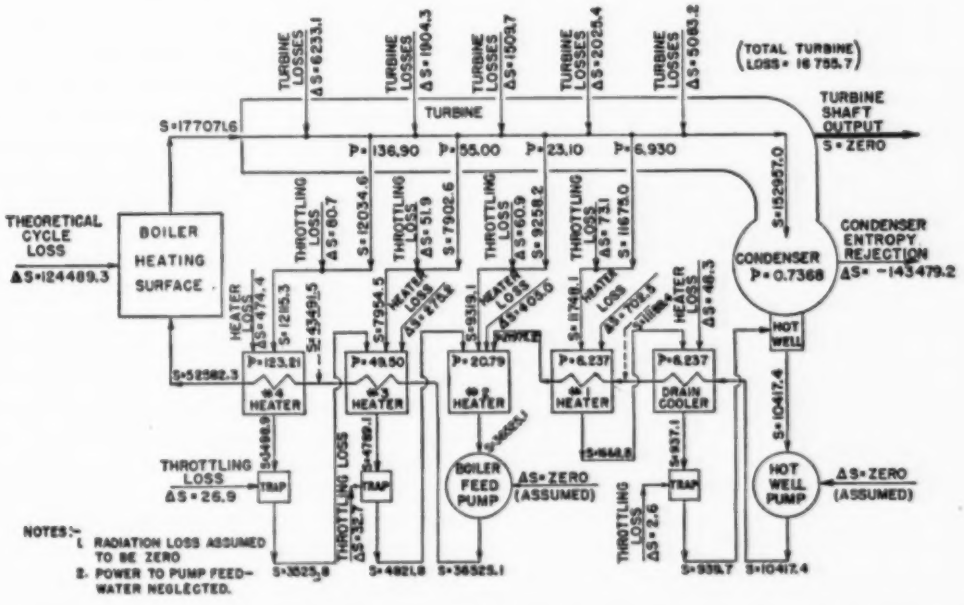
total entropy of the thermodynamic fluid is increased whenever a cycle loss takes place.

Mr. Keller prepared a conventional heat balance diagram and an entropy balance diagram for a 11,500-kw "Preferred Standard" turbine-generator operating at rated load. The latter is based on the flows given in the heat balance diagram, entropy flow being determined by the product of mass flow and specific entropy. Whenever the total entropy leaving a given piece of apparatus is greater than that entering, the difference is the entropy increase caused by the cycle loss taking place in the apparatus.

A table was constructed to illustrate how an overall picture of power plant losses may be prepared by means of the entropy balance diagram. Shown in the table are entropy increase and corresponding power output losses in terms of kilowatts and percentages of turbine and boiler output. Values from the table may be used to capitalize each of the individual power plant losses.

In extracting superheated steam for feedwater heating purposes, there is generally a loss relative to extraction of wet steam. Temperature of feedwater leaving a heater is usually determined by the pressure of extracted steam without regard to its superheat. Even when the heater is designed to use superheat, the temperature of the leaving feedwater is many degrees below that of the extracted steam. A curve was plotted to show the loss in the feedwater heating cycle that is caused by superheat in the extracted steam.

The author concluded with the observation that the entropy balance method is a fundamentally sound and easily applied method of isolating and evaluating power plant losses. It is not a substitute for other methods of analysis but does provide another approach.



Typical entropy-balance diagram for above unit.

High-Pressure By-Product Steam Plants

J. D. Yoder of The Permutit Company and **W. L. Webb** and **T. Baumeister** of the American Gas and Electric Service Corp. were the authors of a paper which demonstrated that increased power production can be obtained by exhausting high-pressure turbines direct to process rather than to coils of evaporators used to produce process steam. Even the most efficient condensing power plant wastes approximately 50 per cent of the heat supplied in fuel as low-grade heat in the cooling water of the condenser. On the other hand, when turbines exhaust directly to process, power is generated through the full steam expansion from boiler pressure to process steam pressure, and the heat rate approaches the mechanical equivalent of heat or 3413 Btu per kwhr.

There are two common methods of utilizing turbine exhaust steam: (1) by exhausting to evaporator coils which deliver process steam at some practical lower pressure and (2) by exhausting directly to process headers. Advantages of the first method center principally upon the return of condensed steam from evaporator coils, thereby avoiding large amounts of makeup and extensive continuing water treatment. The second method involves substantially 100 per cent treated makeup, but with accumulated operating experience it has been demonstrated that this amount of makeup can be delivered to 1400-psi boilers without operating hazard and greatly increased generation of by-product power.

Studies were made of the relative amounts of by-product power that can be produced from a 1400-psi boiler to obtain 100,000 lb per hr of 215-psia process steam using turbines exhausting to evaporator coils; also exhausting directly to process and using either softened or demineralized makeup. Passing steam through evaporator coils with turbine exhaust at 430 psia, the turbine produces 2920 kw of by-product power as compared with 4190 kw when exhausting at 270 psia. With turbines exhausting directly to process and 100 per cent makeup, the by-product power for softened feedwater and demineralized feedwater is 5340 kw and 5620 kw, respectively. When using demineralized instead of softened makeup, the increased power results from less blowoff and less degradation of heat. Also, with less blowoff, more steam must pass through the high-pressure turbine to provide the necessary heat in the feedwater, which additional flow increases the by-product generation.

Process steam installations in which the high-pressure turbine exhausts to evaporator coils and in which the turbine exhausts directly to process (one hundred per cent softened makeup being supplied to the boiler) were placed in service at the Deepwater Operating Company's station in Deepwater, N. J., in 1930 and 1942, respectively. Both employ nominally 1400-psi, 725-750-F initial steam conditions at the turbine throttle and supply 215 psig steam to process.

In the 1942 installation, which requires 100 per cent makeup, the raw water is treated for reduction of turbidity, color, silica, and hardness. Operating experience has indicated that sedimentation and color and silica reduction can be accomplished in one step when using ferric sulfate and lime.

In discussing the economics of by-product power installations, the authors found that the overall investment requirement justifies the selection of high-pressure turbines exhausting directly to process in preference to those exhausting to process evaporators.

They state: "The investment for a high-pressure boiler makeup treating plant alone is substantially the same as an evaporator plant alone for the same process steam capacity. The complete power plant, including boilers, turbines, buildings and auxiliaries, as well as the process steam equipment, is bound to require more investment for the installation exhausting directly to process. The turbine-generator is nearly twice the size and the boiler must be larger."

For a given process steam output, say 400,000 lb per hr at 215 psia, experience has shown that (*a*) increased by-product power may be obtained at current prices for an investment increment of approximately $100 per kw, and (*b*) the increment of production cost of electrical energy as produced by the unit exhausting directly to process as compared to the turbine-evaporator unit is less than the total production cost of a condensing plant using the same fuel.

When it is recognized, in addition to the foregoing favorable factors, that the unit exhausting directly to process operates without undue labor or maintenance costs and without sacrifice of reliability, the overall economic picture favors this solution of the problem of the multi-purpose steam power plant.

Furnace Performance Factors

The second phase* of the investigations of the Special Research Committee on Furnace Performance Factors dealing with furnace heat absorption when burning pulverized coal was reported in three parts. Part 1, by **R. I. Wheater** and **M. H. Howard,** both of Foster-Wheeler Corporation, dealt with variation of heat absorption as shown by measurement of surface temperature of the exposed side of furnace tubes. Part 2, by **R. C. Corey** and **Paul Cohen,** both of the U. S. Bureau of Mines, dealt with heat absorption efficiency as shown by temperature and composition of gases leaving the furnace. Part 3, by **H. H. Hemenway** and **R. I. Wheater,** both of Foster-Wheeler Corporation, contained a comparison and correlation of the results of the investigation.

The unit upon which the studies were made is rated at 640,000 lb per hr at 950 psig and 900 F steam temperature. Installed at the Paddy's Run Station of the Louisville Gas & Electric Company, it is of the single-drum, Foster-Wheeler type with dry-bottom furnace and fired by eight horizontal intervane turbulent burners located in the lower front wall and arranged in two horizontal rows of four burners each.

The object of Part 1 was to establish the distribution and amount of heat absorption in the furnace as measured by the ΔT method for the various operating

* The first phase of this investigation was carried out in 1945 on a 475,000-lb per hr, 1375-psig, 925-F Combustion Engineering unit equipped with vertically adjustable tangential burners and dry-bottom furnace, and installed at the Tidd Station of The Ohio Power Company, Brilliant, Ohio. The results were reported in four papers at the A.S.M.E. Semi-Annual Meeting at Chicago, in June 1947.

conditions investigated and to study the effect of these variables on furnace performance. The operating variables were burner adjustments, furnace rating, excess air for combustion and different combinations of burners in service at half load.

Conclusions of Messrs. Wheater and Howard, in the first paper, were as follows:

1. Ash does not collect in sufficient quantities at such load to affect the heat absorption by furnace wall surface at any location other than on the rear wall at burner elevation.

2. Average absorption rates are usually highest at the elevation just below the burner level, although the maximum might be found at the burner elevations if it were not for ash coverage. A second peak of high absorption rates occurs at the elevation where the cross-sectional areas of the furnace is reduced, near the top.

3. Variations in absorption rates for a clean furnace do not exceed 3 to 1, or 4 to 1.

4. Opening of the secondary air vanes, in the ranges studied, causes: (*a*) a reduction in heat absorbed by the front wall; (*b*) an increase in ash accumulation on the rear wall opposite the burners; (*c*) a reduction in absorption rates in the zone of higher absorption on the side walls near the burners; (*d*) decrease in absorption at burner elevations, as well as lower absorption rates throughout the furnace; and (*e*) a decrease in furnace efficiency.

5. Increasing the excess air from 17 to 30 per cent causes: (*a*) reduction in heat absorption at burner elevations; (*b*) an increase in ash coverage on the rear wall opposite the burners; and (*c*) decrease in furnace heat absorption efficiency.

6. Variations in the combination of burners in service at half load causes: (*a*) changes in ash on the rear wall opposite the burners; (*b*) variations in the average absorption rates at the burner elevations, as well as in the locations of higher absorption zones; and (*c*) variations in furnace heat absorption efficiency by about 5 per cent.

Determination of the total heat absorption in the furnace, as reported by Messrs. Corey and Cohen, was arrived at by taking the difference between the heat input, corrected for losses, and the sensible heat in the furnace-outlet gas. The effects on furnace heat absorption of load, excess air, burner setting and, at low loads, the number and location of burners in service were studied.

At full load the furnace heat absorption was found to decrease with both increase in excess air and opening of the secondary-air vane settings. However, the effect of excess air was independent of secondary air-vane setting, and vice versa.

At three-quarter load the efficiency decreased about 0.6 per cent for an increase in secondary-air vane opening from 35 to 60 per cent.

At half load, with eight burners operating, the secondary-air vanes had to be set at 30 per cent open for good operation, whereas with four burners a setting of 50 per cent open was found most desirable. The furnace heat-absorption efficiency was highest when the four lower burners were used.

For otherwise constant conditions, furnace heat absorption increases and furnace heat-absorption efficiency decreases as the heat available in the furnace increases.

Analysis of the test results indicates that the area of the envelope of hot gases must be considerably less than that of the heat-receiving surfaces.

The comparison and correlation of results, as expressed by Messrs. Hemenway and Wheater in the third paper, contained the following conclusions:

1. That with care in testing, furnace performance may be determined by either the heat balance method or the ΔT method with a fair degree of accuracy.

2. That the overall average heat transfer coefficient, U_0 through the tube wall and inside tube film, was 1030 to 1050 Btu per sq ft of projected area per hour per deg F. From this the calculated film coefficient is 5500 Btu per sq ft of inside tube wall surface per hour per deg F.

3. That for eight-burner operation with secondary air vanes 40 per cent open, the average furnace heat absorption rate Q, the average furnace exit gas temperature, T_0, and the average furnace tube-face temperature T_w, are related by the expression

$$Q = 1060\left[\left(\frac{T_0}{1000}\right)^4 - \left(\frac{T_w}{1000}\right)^4\right]$$

Effect of Pressure on Combustion of Pulverized Coal

Citing the results of several earlier theoretical studies dealing with the ignition of pulverized coal at atmospheric pressure, which indicated a decreased initial heating rate with increased pressure, **T. T. Omori,** of California Institute of Technology, and **A. A. Orning,** of Carnegie Institute of Technology, described a laboratory setup and procedure for investigating this problem. Also studied, was the effect of both total pressure and partial oxygen pressure with controlled ignition conditions. The following results were observed:

The burning particles were generally incandescent for only a small portion of the distance across the combustion chamber. Nevertheless, the degree of completeness of combustion, even at temperature levels giving uniform ignition, increased strongly with increasing temperature, increased moderately with partial pressure of oxygen, and was strongly depressed by increasing total pressure.

Ability to consume the oxidizing gas as rapidly as it can reach the burning surface depends upon the particle temperature. Since the heat capacity of the particle is relatively small, compared to its heat of combustion, this temperature is such as to obtain a balance between the rates of heat release and heat dissipation to the surroundings. Heat loss to the immediately surrounding gas should depend upon pressure, but this appeared contrary to the relative effects found.

The resulting data fully confirmed the indications of the earlier theoretical studies that decreased initial heating rates under elevated pressure would lead to less complete combustion, despite the beneficial effect of increased partial pressures of oxygen.

Gasification of Pulverized Coal with Oxygen and Steam

Many methods have been proposed for the gasification of coal in the production of synthesis gas, among the most promising of which appears to be employment of pulverized coal in suspension in a stream of oxygen and steam. The apparent advantages are (1) relatively high specific rates of gasification due to the high specific surface of the fuel; (2) ease of control and small plant size with such a continuous process; and (3) use of any class of coal.

Predicated on previous investigations on the use of a vortex reaction chamber by the Fuel Research Board in England and by the Locomotive Development Committee in the United States, as well as German experiments with suspension gasification of pulverized coal with oxygen and steam under turbulent conditions, the U. S. Bureau of Mines designed and built a pilot plant to gasify 100 lb of coal per hour at its Pittsburgh Station. This was described and the results of numerous tests reviewed in a paper, or progress report, by **H. Perry, R. C. Corey** and **M. A. Elliott.**

The tests confirmed the assumption that from a knowledge of feed conditions, heat losses and the per cent carbon gasified, the approximate composition of the gas produced can be predicted with the vortex reactor. However, the earbon conversions were low and the resulting gas was high in carbon dioxide. In fact, for the reactor to be commercially feasible, the carbon conversions would have to be increased. Therefore, for a given set of feed conditions any means of increasing the carbon conversions would improve the quality of the gas.

Several possible methods of accomplishing this were suggested, such as employing a coarser size consist of coal with a spinning-plate distributor, increasing the reaction chamber height, and increasing the tangential velocities at constant coal rates. These will be investigated in further tests that are planned.

Coal Handling Mobile Equipment

Two papers at the first fuels session dealt with the experiences of two electric utilities in adopting bulldozer-carryall units for storing and reclaiming coal.

The first, by **E. C. Russell,** dealt with the practice of the Philadelphia Electric Company which, prior to 1946, had stored coal in piles between parallel tracks by means of clam-shell cranes with 60-ft booms. On reclaiming, coal was loaded into company-owned hopper cars that were switched by a locomotive over track hoppers from which a conveyor system supplied the plant bunkers. For storing coal these same hopper cars were loaded at the coal tower by chutes.

During that year a number of rubber-tired, diesel-propelled units of the heavy earth-moving carryall type were purchased and put into service. These have a maximum speed of over 14 mph and a scraper capacity of 12 to 15 cu yd; in fact, they have sufficient power to move their loads at relatively high speed up a 10-per cent grade and unload while moving, but need assistance in loading on the reclaiming cycle. This assistance is provided by track-type bulldozer tractors.

With the mobile equipment coal piles of greater height are possible, and the method of unloading allows the coal to be laid down in thin layers. Rolling or any other method of compaction as a fire preventive is unnecessary, as the mobile equipment has increased the density of the piles from 60 to 69 lb per cu ft. Moreover, an increased quantity of coal can be stored in a given area. Spot checks have indicated that a scraper is capable of reclaiming 70 to 90 tons per hour and will store better than 100 tons per hour. A substantial saving is made in the labor required compared with that in the old system. However, the author observes that, inasmuch as such mobile equipment is built primarily for moving earth, which has a density about twice that of coal, improvements could be made to permit them to carry a greater volume of coal.

The second paper on this subject, by **J. N. Ewart,** dealt with practice at the Oswego Station of the Buffalo-Niagara Electric Corporation. Here the bulldozer-carryall, earth-moving equipment has handled in excess of three billion ton-feet of coal during its first nine years of operation.

Although provision is made for either rail or lake delivery of coal, all the coal is received by self-unloading boats which discharge directly to either a receiving hopper or to one end of a 1400 × 400-ft stocking pile, which at times reaches a height of 100 ft and has contained as much as 560,000 tons of coal. The reason for this huge storage is that a year's supply is obtained during the open navigation season which approximates 6 months. The coal is moved into storage from the discharge of the self-unloader, or from the stocking pile entirely by means of bulldozer-carryall units. Starting at the stocking pile the mobile unit picks up a load of 13 tons, carries it an average of 700 ft to the spreading area and lays it down in a ribbon approximately 13 ft wide, 40 ft long and 10 in. thick, and then returns for another load. The round trip requires about 10 minutes.

Reclaiming is also entirely by means of the bulldozer-carryall units.

There have been no fires in this coal pile to date, although portions of it have remained untouched for as long as three years. Furthermore, experience has indicated that many of the usual rules for successful storage of coal can be violated if the coal is laid down in thin layers and adequately compacted. For example, no effort is made to avoid segregation, though coal may be purchased from as many as sixty mines, varying in volatile from 17 to 37 per cent, sulfur 1 to 3 per cent, and sized from fine slack to double-screened and run-of-mine.

Average figures over the last four years, during which over $2^1/_2$ million tons were handled, shows, in cost per 1000 ton-feet, 6 cents for operating labor, 0.6 cent for fuel, 3 cents for maintenance labor and 1.6 cents for maintenance materials, thus making a total of 11.2 cents. Or, expressed differently, the 700-ft out-haul cost was 7.8 cents per ton and the 500-ft reclaiming cost was 5.6 cents per ton.

These operating costs are exclusive of fixed charges on the capital investment which has increased as the station capacity expanded. With a present station

capacity of 240,000 kw, there are four bulldozer units and three carryalls which represent an investment of slightly over $73,000.

Design of Cyclone Dust Collectors

Melvin W. First of the Harvard School of Public Health reported on a study of flow patterns and dust distribution with relation to cyclone proportions in a paper entitled "Cyclone Dust Collector Design." For the experimental work geometrically similar cyclones having diameters of 4, 8 and 12 in. were constructed of transparent plastic. The proportions of the experimental models approximated an average tangential rectangular-inlet cyclone collector. Provision was made for varying exit duct diameter, exit duct length, inlet height and width, height of cone and addition of an inlet vane. The test dust was composed of glass spheres having a mean size of 9 microns and a standard geometric deviation of 1.76.

Flow patterns for the three sizes of cyclones were found to be remarkably similar. There was very little difference in total energy loss for the different sizes of apparatus having the same flow velocities, indicating that wall friction is a very negligible source of energy loss in the cyclone. The experiments also confirmed findings of previous investigations that the length of the exit duct inside the cyclone had little effect on overall energy loss.

The use of entry vanes greatly reduces gas velocities by comparison to cyclones without them. The angle of flow in both ascending and descending streams is markedly increased. Low velocity, little lapping of streams and large downward and upward angles of flow to speed the fluid through the cyclone with the fewest number of turns all act to produce low energy loss.

The following conclusions were reached in regard to dust collection efficiency:

1. Since entry width controls gas stream width, it is an important variable in cycle efficiency. Gas stream width controls the radial distance that particles must traverse to reach the cyclone wall and be separated by centrifugal force. As radial distance is decreased, a lower tangential velocity (less energy loss) is required, and smaller particles may be successfully separated for a given air flow rate.

2. With narrow inlet widths and no entry vane, a major portion of the separating action is accomplished at entry. This is because dust is confined to a radial distance one half the entry width from the cyclone wall.

3. Cyclone efficiency may decrease for very high entry velocities due to the lapping effect of successive high velocity gas streams. Downward particle movement is retarded under these conditions, and each complete turn in the upper section of the cyclone results in retained dust being displaced nearer the cyclone axis, where it eventually descends the outer exit duct wall and finds its way into the exit duct.

Mr. First summarized his findings in these words: "Quantitative investigations of velocity, static pressure and flow direction in cyclones of various designs and sizes demonstrate that energy loss is directly related to internal cyclone velocity, and that energy loss results from internal shear of adjacent gas strata rotating at different speeds and at different flow angles. Cyclone dimensions found to be significant in cyclone energy loss are entry height and width, exit duct diameter, the ratios of cylinder and core height to cyclone diameter, and the presence or absence and type of entry vane. Entry vanes completely closing off the annular space in the cyclone induce a double-eddy type flow in the upper half. All other designs show a well-defined double spiral flow.

"Dust studies indicate that cyclones having narrow entries without vane possess important advantages for high efficiency performance. Dust gradients show that gas flow rate is not a major variable in determining cyclone efficiency."

Fly-Ash Symposium

Four papers made up a symposium on the uses and disposal of fly ash. These were "Present and Future Magnitude of the Pulverized-Coal Fly-Ash Disposal Problem," by **H. S. Walker,** director of research of The Detroit Edison Company; "Use of Fly Ash in Concrete," by **Walter Handy** of Combustion By-Products Company; "Use of Fly Ash in the Bitumastic Road Industry," by **C. M. Weinheimer,** The Detroit Edison Company; and "Some New Developments in the Use of Fly Ash," by **M. C. Randall,** of Philadelphia Electric Company.

Mr. Walker mentioned a survey that had been made in which questionnaires were returned by 79 utilities and 24 industrials, the former accounting for 65 per cent of the coal-generated energy produced by public utilities in this country. The utilities reported 2,241,547 tons of fly ash collected annually and the industrials 110,907 tons, making a total of 2,352,454 tons. At an average disposal cost of 67 cents per ton the total disposal cost was in excess of a million dollars a year, which figure will be greatly increased by the new large stations that will go into service in the next year or two. The investment in fly-ash collection equipment by the private utilities now reaches 30 million dollars. On the other hand, the revenue obtained from the sale of fly ash by five utilities reporting amounted to a total of $135,624, at an average selling price of 90 cents per ton.

Analysis of the ash, as reported in the questionnaires, showed carbon, iron as Fe_2O_3 or Fe_3O_4, magnesium oxide, calcium oxide, Al_2O_3, SO_3, titanium oxide, carbonate as CO_3, silicon as SiO_2, and phosphorus as P_2O_5—all in widely varying percentages. The fusion temperature ranged from 1910 to 3000 F and the amount retained on a 325 mesh from 8 to 95 per cent.

As to attempted commercial uses of fly ash, Mr. Walker listed: (1) substitute for fuller's earth in filters—not very satisfactory; (2) substitute for pumice—not satisfactory; (3) in paints—not satisfactory; (4) substitute for sand in fertilizer—satisfactory but cost and handling higher; (5) bitumastic road construction—successful; (6) an inert filler in low cost rubber—not commercially satisfactory; (7) as a soil amendment agent—satisfactory, but few revenue-producing potentialities; (8) as a fine aggregate in cinder concrete—satisfactory; (9) as facing sand in light metal foundries—satisfactory; (10) special sand-blasting—suc-

cessful, but limited market; (11) gravity water filters—not satisfactory; (12) in putty and caulking material—not satisfactory; (13) in building blocks—satisfactory but market dependent on local conditons; (14) in concrete as partial replacement for cement—very satisfactory; and (15) substitution for clay in manufacture of portland cement—some favorable reports.

The present principal commercial uses are in the partial replacement of cement in concrete construction and in cinder blocks, brick, asphalt, and bitumastic road construction.

Dealing with the use of fly ash in concrete, Mr. Handy stated that fly ash affects the properties of concrete as follows:

1. Water requirements are about the same as that for portland cement.
2. It improves the workability of the concrete mix by making it more plastic and decreasing segregation.
3. When replacing part of the portland cement it is an effective strength-producing material in compression, although it takes 14 days or more to develop the same strength as portland cement.
4. Fly-ash cements have a lower heat of hydration.
5. Concrete containing portland pozzolanic cement derived from natural pozzolan tends to shrink more upon drying than do concretes of the same mix containing only portland cement. The effect on drying shrinkage of 40 per cent fly ash and 60 per cent portland cement is small.
6. Replacement of a part of the cement with fly ash increases the resistance of concrete to the disruptive action of freezing and thawing.

Because of the tonnage involved, the bitumastic road industry offers definite opportunities for fly-ash disposal. According to Mr. Weinheimer, The Detroit Edison Company investigated this field as early as 1931, but it was not until 1939 that such use was approved. Since then the number of users and the tonnage so used have been ever increasing. The chemical composition of this fly ash does not differ greatly from the natural filler found in Trinidad asphalt; it is hydrophobic, and has good void-filling capacity; it contains in per cent by weight, as collected, 45.9 SiO_2, 26.9 Al_2O_3 and 9.1 Fe_2O_3. When burned free of carbon, these percentages are slightly greater.

Since the demand for fly ash in the road industry fluctuates widely, The Detroit Edison Company has provided dry storage of approximately 2000 tons capacity. During 1948, it sold 31,200 tons of fly ash for such use.

Mr. Randall discussed four products which give promise of absorbing an appreciable quantity of fly ash. These are insulating cements, building brick, soil stabilization compound, and foundry work.

Characteristics that make fly ash suitable as an insulating cement are good workability and coverage, and low shrinkage so that a single coat can be applied without use of wire mesh, and paint can be applied directly without the usual canvas jacket.

In the production of brick, low-carbon fly ash, as a substitute for clay, is desirable, although the carbon content may run as high as 12 per cent without detrimental effect. The range of composition that will produce a good brick extends from 80 per cent fly ash and 20 per cent slag to 40 per cent fly ash and 60 per cent slag. It is processed the same as shale brick and the firing temperature ranges from 1750 to 1950 F.

Experimental installations have been made utilizing Cor Crete (limestone screening, fly ash, and a small amount of hydrated lime) as the wearing surface on parking lots, driveways and walkways, which thus far appear satisfactory. A compressive strength of 1000 psi can be realized with this mixture in 28 days.

During the war the Aluminum Company of America used large quantities of fly ash in foundry work and the Olney Foundry of Link Belt Company in Philadelphia now uses two parts fly ash to twenty parts sand as a lubricant in the conglomerated mass of sand, phenol and other resinous binders when blowing cores. Also, in the steel foundries fly ash is being used to a limited extent to provide hot strength for core and molding sand, as a replacement for silica flour.

Discussion

The large attendance at this session and the discussion following presentation of the papers reflected the wide interest in this subject. The following points were brought out:

1. Whereas some utilities have developed a market for fly ash, others are so situated that they must pay for its disposal or if possible to pump it to fill. For instance, the Consolidated Edison Company of New York, which must dispose of vast quantities of fly ash, cinders and slag, employs scows at Waterside and East River Stations for dumping the loads at sea, whereas at Hell Gate and Sherman Creek Stations the mixture is carted away by trucks. Disposal costs amount to 58 cents per cubic yard.
2. In some localities, particularly in New Jersey, fly ash is being employed extensively in concrete road construction with 120 lb of fly ash to every 5 lb of cement. It has also been accepted for pavement work in and around Detroit and Chicago.
3. In many localities the demand in construction work is seasonal, whereas the supply is continuous. To get around this one company has set up storage facilities for the fly ash collected.
4. The U. S. Bureau of Reclamation is employing fly ash in the concrete mix for the Hungry Horse Dam in Montana, and it has also been employed in foundations for some new power stations.
5. When used for fill, its bearing strength is better than that of clay.
6. The setting time of a fly-ash mix, in order to attain maximum strength, is longer than that of ordinary concrete, 28 days being considered desirable where it replaces as much as 40 per cent of the portland cement. Moreover, it must not be subjected to vibration while setting.
7. A process has been developed and will soon be pushed to employ fly ash as an aggregate in making light weight blocks that weigh only 60 per cent of cinder blocks.
8. Some investigations are in progress with a view to recovering certain rare metals from fly ash.

9. Since fly ash varies greatly in composition, it is important to keep the specifications broad. About 10 per cent carbon content is considered as the upper desirable limit.

10. There is need for greater coordination between the various groups that are working on the problem.

Sulfite and Silica in Boiler Water

Experiences with potassium sulfite decomposition and silica deposition resulting from boiler feedwater at the Springdale Station of West Penn Power Co. were related by **L. E. Hankinson** and **M. D. Baker.** The installation under consideration was of the single-boiler, single-turbine type, which furnished an opportunity to make a closely controlled study of the water conditions in the boiler and turbine.

There were three original boiler water sampling points which were selected so that the samples would be representative of differences, if any, in chemical constituents or concentration at three different parts of the boiler. Chemicals used in boiler water conditioning for this particular unit have always been potassium salts, including K_3PO_4, KOH, KCl and K_2SO_3, and were introduced into the boiler water at the drum.

Early in the operation it was noted that sulfite analyses of boiler water were erratic and that it was difficult to maintain the desired concentration. Water samples also contained various quantities of finely divided black iron and copper oxides. These conditions, and particularly the unpredictable results of the sulfite analysis, caused much concern and led to the boiler water investigation.

Six months after the boiler was placed in service intermittent shots of H_2S were discharged at the main condenser air ejector. This condition grew worse with time and polluted the turbine room air to the extent that it became offensive to the operators.

Boiler water treatment was fed directly into the drum through a chemical feed bottle once a day. While not a constant occurrence, the heaviest discharge of H_2S occurred 45 to 90 minutes after adding chemicals. It was thought that faulty boiler circulation might be the cause of sulfite decomposition, and accordingly it was decided to install additional sampling coils to determine points of high concentration. Also, a chemical feed pump was placed in service to provide continuous treatment.

After this pump had operated for some time there was a reduction in the intensity and frequency of H_2S shots discharged by the air ejector, but seven months elapsed before the condition was entirely eliminated.

Acid cleaning of the boiler took place in April, 1947, and more than 500 lb of deposit were removed as a result of this cleaning and the subsequent washing of the drum and headers. The turbine was inspected at the same time, and there was evidence of active corrosion of the casing at the discharge throat into the condenser. Also, the metals of the condenser were attacked where the condensed steam rained into the condenser. This was likewise the case with the air ejector condenser, all attacks being attributed to H_2S. No active corrosion has been observed in subsequent inspections after the disappearance of the H_2S.

A probable theory to account for the H_2S formation is that high concentrations were built up at the time of shot treatment, resulting in sulfite decomposition. The air ejector did not discharge all the gas, the remainder being absorbed by the condensate and recirculated in the boiler water cycle. When the H_2S was in this state it produced an acid solution that attacked the metals of the system. These dissolved metals when finally concentrated in the boiler would settle out as oxides, but during the conversion from sulfide to oxide they served as catalysts to break down more of the sulfite. The use of acid cleaning and the elimination of sulfite excess by continuous chemical feed gradually established the desired boiler water condition and reduced the H_2S.

However, some inconsistent sulfite analyses still persisted, and it was noted that samples collected through copper tubing gave erratic results by contrast to the consistent values obtained through steel sampling lines. After it was determined that copper would reduce sulfite in boiler water samples, all permanent boiler water sample connections and coils made of copper were replaced by steel. A few other tests and studies were made, but all the data indicated that the boiler was free of circulation trouble.

Fly Ash a Source of Silica

The rate of deposition of silica on turbine blades at Springdale confirmed the findings of Straub and Grabowski that silica concentrations in boiler water in excess of 5 ppm will cause deposits. The rate of deposition is measured in this installation by the increase in pressure at No. 3 bleed point, and it was found that, with a silica content of between 18 and 25 ppm, pressure built up over a period of months to a point where turbine load had to be reduced.

All known sources of silica were investigated and eliminated. That due to evaporator carryover was minimized by maintaining the evaporation rate at or below 50 per cent of capacity. Raw water contamination could not be found. The possibility of silica in water-conditioning chemicals was investigated and found negligible. Analytical procedure was verified and found correct, but even with these possibilities eliminated, unexplained sudden increases of silica content in the boiler water were experienced.

It was discovered that there was a relationship between silica increase and the direction of the wind. When this apparently absurd observation was investigated, it was found that with a certain wind direction fly ash from the stacks was blown into an open vent and entered the boiler feedwater system. Further investigation disclosed that when the manhole lid on a condensate water storage tank was off, large quantities of fly ash from the induced- and forced-draft fans and from the hydromix valves for removing material from the precipitators were drawn into the condensate tank. Corrections were made, and the unexplained high peaks in the silica content of the boiler water have been reduced though not entirely eliminated.

Messrs. Hankinson and Baker concluded that the boiler water circulation is satisfactory, continuous chemical treatment is necessary for satisfactory conditioning, steel should be used for sampling lines, hydrogen sulfide can produce severe corrosion, and silica con-

tamination of the feedwater system may occur because of a failure of design engineers to recognize the possibility of contamination by fly ash.

Sodium Phosphate Hide-Out

A form of sodium phosphate hide-out in boilers operating at 1600 to 1700 psi that differs from normal hide-out was reported in a paper by **Prof. F. G. Straub** of the University of Illinois. In a case cited, during operation of the boiler the phosphate was added continuously along with sodium hydroxide so as to keep a residual of 20 to 40 ppm as Na_3PO_4 and a pH around 11. When the rating was reduced, the soluble phosphate would increase to around 200 to 300 ppm, but the free hydroxide would be reduced from about 40 ppm to zero. This loss of phosphate with its subsequent reappearance, accompanied by the loss of hydroxide, indicated that it was not hiding out as trisodium phosphate but as a form more on the acid side, such as mono- or disodium phosphate. Moreover, after two or three months operation difficulty was experienced through failure of wall tubes. These bulged with no indication of corrosion on the water side, although heavy deposits of calcium and sodium phosphate were found on the water side of the tubes facing the furnace. When the boiler pressure was reduced for a short period to around 1300 psi, this peculiar type of hide-out did not take place.

Tests were then made on a small laboratory boiler in which an attempt was made to duplicate these phenomena under more flexible conditions that were susceptible to close study, and the deposits on the tubes were subjected to X-ray diffraction analysis.

The test boiler was then modified to provide different circulation conditions, and the investigation repeated.

While definite conclusions were lacking, the results seemed to indicate the following:

1. At temperatures corresponding to 1700 psi and above, there is present a stable insoluble sodium phosphate which will form as a deposit on the heating surfaces.

2. Anything that tends to raise the boiler-water temperature will precipitate more of this slightly soluble phosphate. Thus a heavy deposit of calcium phosphate at the heating surface will raise the water temperature at this location and cause precipitation of the insoluble sodium phosphate. A high rate of heat input may cause temperature increase and start phosphate deposition.

3. The potassium phosphate does not form an insoluble salt at these temperatures; and if the ratio of sodium to potassium can be kept low, it is possible to use potassium salts instead of the sodium.

Degasser for Steam Sampling

Because of the accuracy and ease with which the electrical conductivity of steam condensate can be measured, conductivity procedures are widely preferred for precise determination of steam purity. Interpretation of the conductivity measured directly on a condensed sample is frequently uncertain, however, because gases such as carbon dioxide and ammonia also contribute to the conductivity. Either these gases must be removed before measuring the conductivity or they must be determined by chemical analysis so that suitable correction can be applied. Therefore, to avoid this time-consuming procedure, an automatic steam sample degasser capable of continuous determination of steam purity by conductometric means is desirable.

A variety of devices have been developed to remove gaseous impurities from steam samples—generally by first condensing the sample completely. The resulting condensate is then either distilled, aerated, or subjected to vacuum in order to expel the dissolved gases, which techniques are reasonably effective for removing gases present in simple solution. However, gases which can contribute to conductivity, such as carbon dioxide and ammonia, react with water and form ionized compounds.

A paper by **H. M. Rivers,* W. H. Trautman*** and **G. W. Gibble†** described in detail a recently developed automatic degasser, manufactured by the Hagan Corporation, which eliminates this problem by preventing the gases from becoming dissolved to any appreciable extent in the first place. The results of field tests in some 25 plants were cited, showing that in practically all cases the effect of gases in the steam had been eliminated.

* With Hall Laboratories, Pittsburgh, Pa.
† Formerly with Hall Laboratories; now with Arabian-American Oil Co. Saudi-Arabia.

Turbine Oil Maintenance and Purification

At a Symposium, held under the auspices of the Petroleum Division, **H. J. Klotz,** chief power engineer of Stone & Webster Engineering Corporation, stressed the importance of properly maintaining turbine oil with 3600-rpm machines and increased shaft temperatures due to present-day high steam temperatures.

Although the necessity of guarding against the entrance of water into the oiling system and accumulation of corrosion products is generally recognized and precautionary steps taken, a few sad experiences have resulted from entrance of water into bearings, due to gland leakage, and resulted in deterioration of the oil with accompanying corrosion. Therefore, it is now general practice, in addition to insuring tightness of turbine glands, to clean thoroughly the oil tanks and all connecting piping and maintain this condition.

Features essential to satisfactory service from turbine lubricating oil were listed as follows:

1. Selection of an oil of suitably high quality—a matter that is not difficult owing to the excellent job refiners have done in supplying high-grade oils to meet the specifications of turbine designers.

2. Maintenance of the lubrication system in the highest possible state of cleanliness.

3. Maintenance of the oil in satisfactory condition, through suitable equipment for cooling and prompt removal of foreign material.

4. Constant vigilance is important to insure maintenance of quality in the desired range. This involves scheduled frequent laboratory testing of service samples, as well as visual inspection.

A survey of twenty-two representative plants, covering a wide range in turbine sizes and steam conditions, showed that all have adopted continuous bypass conditioning of the oil with the use of bag filters for all units installed since 1942, although many of the earlier units employ intermittent bypass filtration. Other earlier units rely on periodic removal of the entire batch of oil for rest and reconditioning after periods varying from 8000 to 16,000 service hours. In some cases the batch reconditioning supplements the intermittent bypass filtration and frequently centrifuging is included in the batch reconditioning process. The success in maintaining the quality of the oil by continuous bypass filtration is indicated by the fact that many units are operating with the original oil, plus necessary nominal makeup, after periods up to 9 years.

A few of the plants assist in maintaining the quality of the oil by withdrawing from 10 to 15 per cent yearly for use in station auxiliaries and replacing the oil removed from the main unit with new oil.

Removal of vapor from the oil tank is standard practice with all the latest units, and all but two of the plants contacted employ rust preventive coatings in the oil tanks of the later units.

All the operators reported a regular program of testing but, despite the success achieved with present methods of testing, the author believed there is need of a simple stability test which can be depended upon to give ample warning in advance of the actual breakdown of the oil.

Only two of the plants are operating turbines of high capacity at steam temperatures over 900 F with uninhibited turbine oil.

Closed-Cycle Gas Turbine Installations

Three European closed-cycle gas-turbine installations, two for central stations and one for waste heat use in a gas works, were described in a paper by **Curt Keller,** of Escher Wyss Ltd., Zurich, Switzerland. These are now under construction and will start operation in 1950. One is a 12,500-kw oil-fired set for the St. Denis Power Station in Paris. The second, of like capacity, is being built by John Brown & Company, British licensee of Escher Wyss, for the Carolina Port Power Station at Dundee in the north of Scotland to supplement hydro power; and the third is of 1000 kw, also being built by John Brown & Company.

It will be recalled that the author presented a paper on the closed-cycle gas turbine before the A.S.M.E. in 1945, at which time he discussed developments to that date and the future prospects of this cycle. In the introduction to his current paper he reviewed the performance of a 2000-kw oil-fired test unit supplying power to the Escher Wyss works which has operated some 5000 hr since January 1940. Average efficiency on a 1338-hr run with a load between 650 and 800 kw and 1150 to 1200 F gas temperature had been 24.2 per cent.

In the St. Denis unit the high-pressure turbine drives the high-pressure compressor and the low-pressure turbine the low-pressure compressor and generator. Other components comprise an air heater, a heat recuperator, and a combustion-air preheater. Calculated temperature entering the high-pressure turbine is 1229 F at 750 psig, and that entering the low-pressure turbine, after reheat, is 1247 F at 255 psig. A heat rate of about 10,000 Btu per kwhr is expected.

The Dundee unit is similar, except that regulation is simpler and no compressed air accumulators will be necessary.

The paper included a tentative layout for a proposed 12,000-kw, pulverized-coal-fired, gas-turbine plant.

Gas-Turbine Heat-Exchange Equipment

George R. Fusner of the General Electric Co. presented a paper entitled "Heat-Exchange Equipment for a 5000-Kw Gas-Turbine Generator" in which he gave a description of the heat-exchange equipment and discussed design considerations of these auxiliaries to a gas-turbine power plant. The particular physical arrangement cited in the paper involves the use of two regenerators and two intercoolers in parallel.

Compressor-inlet temperatures may be decreased by intercooling, thereby reducing the work to drive the high-pressure compressor, providing more power-plant output for a given turbine output, and increasing the cycle efficiency. An intercooler between the low- and high-pressure compressors also reduces the volume flow to the latter and makes it smaller in size and lower in cost. The net work per pound of air flowing in the cycle is likewise increased, thus reducing the size and cost of machinery for a given power-plant output.

For a gas-turbine power plant having a 9 to 1 pressure ratio, 1500 F gas-turbine cycle and a 75 per cent effective regenerator, the author presented curves to show that the addition of a 90 per cent effective intercooler raises the thermal efficiency from 19.8 to 28 per cent.

In the actual design it was found that the extended surface heat-exchanger proved to be the most economical, and standard generator air coolers were used.

Gains in thermal performance due to adding both a regenerator and an intercooler to a gas-turbine cycle cannot be allocated exactly to the individual pieces of equipment. The cycle under consideration was designed for both intercooler and regenerator, and its thermal performance is considerably lowered if either element is left out.

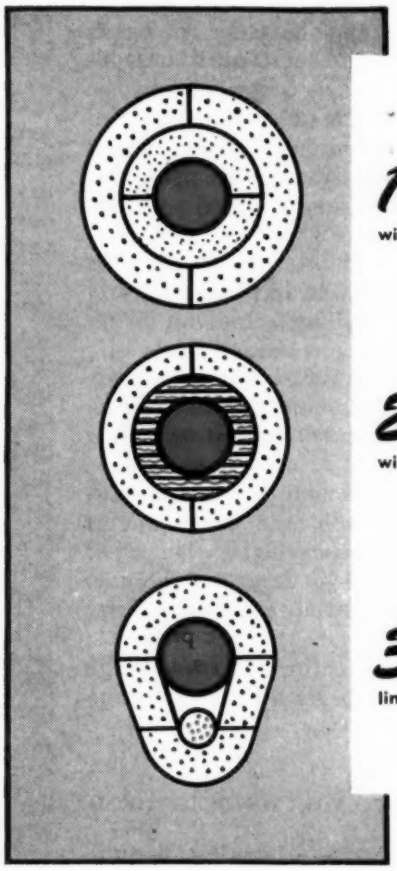
A regenerator is used in a gas-turbine cycle for removing heat from the turbine-exhaust gas and transferring it to the air entering the combustors, thus obtaining a given output with the burning of less fuel. For the gas-turbine plant previously mentioned, the addition of a 75 per cent effective regenerator increased the expected thermal efficiency from 21.1 to 28 per cent.

Because of the uncertainty of tube fouling by the turbine-exhaust gas which may contain ash and unburned carbon, a bare-tube design was selected for the regenerator in preference to the extended-surface type over which the exhaust gases would be required to pass. A regenerator was constructed somewhat like a condenser and gives promise of easy maintenance.

In plants where process steam is needed in addition to electric power, a waste-heat boiler can be substituted for the regenerators. For the particular gas-turbine plant under consideration it is possible to generate 29,500 lb per hr of 200-psig or 34,800 lb per hr of 50-psig steam, assuming a feedwater temperature of 80 F entering the economizer.

How would YOU keep this line hot?

3″ line carrying solution which solidifies at 215° F. but cannot be heated above 250° runs 50′ from one building to another. Operation is intermittent, and pipe must be dismantled daily for cleaning. Which of the three methods shown at the right is best for holding this line at proper operating temperature?



1. Cover with 3″ of 85% Magnesia insulation, with weatherproof metal cover.

2. Surround line with glycol fluid jacket, insulated with standard thick magnesia.

3. Heat with steam tracer line, and enclose both lines in single insulation jacket.

Here's what the Armstrong Engineer recommended

Method No. 2 will work best in this case. But both the others would be practical under slightly different circumstances.

The third method would work well except that the line must be cleaned. With a tracer line enclosed, it is impractical to install the insulation so that the larger pipe can be removed and replaced.

If the first method were chosen, the whole unit—line, insulation, and cover—could be removed together for cleaning. However, this method would not work here because, with intermittent operation, the solution would sometimes solidify and clog the line.

The second method, while most costly of the three, best meets all requirements. The constant bath holds proper temperature at all times. At day's end, the glycol can be drained off and the inner line pulled out for cleaning. Jacket, insulation, and weatherproofing need not be moved.

Of course, this is an unusual case. But there's hardly any heat insulation job, no matter how routine, that can't benefit from a careful study of all its requirements before insulation is specified. That's part of the job of our Contract Service engineers. Their wide experience can help you find the best solution to your heat insulation problems. The complete contracting service they represent also provides quality insulation materials and experienced mechanics to apply them.

FREE BOOKLET

Write today for your free copy of the 28-page booklet, "Armstrong's Industrial Insulations," containing complete information on Armstrong's products and services. Armstrong Cork Company, Industrial Insulation Dept., 9312 Maple Ave., Lancaster, Pa.

ARMSTRONG'S INDUSTRIAL INSULATIONS

MATERIALS INSTALLATION

FOR ALL TEMPERATURES FROM 300° F. BELOW ZERO TO 2800° F.

Some Notes on The Underground Gasification of Coal

An analysis of the results attained at Gorgas confirms other similar experiments in Russia, Belgium and Italy in so far as concerns a low calorific value of the gas. Comparison is made with gas from a conventional gas producer and suggestions are made for improving the product.

By WILHELM GUMZ, Dr.-Ing.*

SUCCESSFUL operation of a gas producer is linked with a number of chemical reactions and physical conditions. The main gasification reactions are endothermic and the heat input, notably the calorific value of the fuel (or its coke), and the heat content of the blast has to cover these heat requirements including the heat losses. The heat output is accounted for mainly by the calorific value and the enthalpy of the product gas and the relatively small external heat losses, as well as the heat and carbon content of the residues. The most important factor controlling the gas quality is the "reaction temperature," by definition the temperature at which heat input and output of the reaction zones of the gas producer balance.

Underground gasification—notably the "streaming method"—has proved rather attractive to mining engineers in many countries; but practical results do not indicate that this method, at the present status of its development, could be readily used for large-scale industrial gas production. It has been demonstrated, meanwhile, that solid fuel *in situ* can be converted into a lean gas for immediate mine-mouth consumption or at least into heat by underground combustion. The possibility of utilizing this heat for steam raising or for power production in a gas turbine may be considered worth while even if the conversion efficiency of heat production is far less than 50 per cent with the mining cost reduced to a fraction of that in conventional mining operations. To consider the chances of further development and to answer the questions as to why success of most of the experiments has lagged behind expectations, some comparisons will be made between the chemical, thermal, and physical conditions of operation for both the standard gas producer and underground gasification practice.

Results at Gorgas

The constituents of gas produced by gasification of coal in the ground at Gorgas, Ala., in 1947 were reported by the Bureau of Mines (1)[1] as follows, representing the average gas composition during that part of the air run where relatively stable conditions and constant back pressure prevailed: 15.2% CO_2, 1.0% O_2, 0.2% Ill., 3.1% CO, 5.5% H_2, 1.5% CH_4, 73.5% N_2; calorific value 46.8 Btu per standard cubic foot (scf).

Analyzing the meaning of this gas composition, produced from a coal with about 38.4 per cent volatile matter and 61.6 per cent fixed carbon (ash-moisture-free basis), the following conclusion might be drawn:

During regular operation, first part of the carbon was burned to CO_2 (independent of the primary reaction) in a long-stretched combustion zone; but due to relatively wide channels and a stratification of gas and air streams unconsumed oxygen was carried farther, even near the end of the "generator" and deteriorated the quality of gas obtained by reduction of CO_2 to CO and H_2O to H_2 and CO. The result, as an extreme case, would be a flue gas of zero calorific value. At the same time, with heat developed either by primary or secondary combustion and transferred to the coal face and by conduction into a certain depth of the seam the coal would be devolatilized. These devolatilization products would be partially burned by excess oxygen (as long as oxygen remained) and partially saved to constitute the main part of the combustible matter in the product gas. The above quoted gas analysis can be interpreted as a mixture of flue gas from burning all the fixed carbon and part of the volatile matter (31 per cent) to $CO_2 + N_2 + H_2O$, leaving the rest of the volatile matter (69 per cent) in the product gas. A more detailed balance is not possible because the composition of the volatile matter at different temperatures has not been reported.

Italian Experiments at Valdarno

Experiments with Italian lignite made by Demart (2) at Valdarno led to the same conclusion. The gas is somewhat better than the gas produced at Gorgas, Ala., because lignite has a higher volatile content. The average calorific value was 89.5 Btu per scf, representing a mixture of 73 per cent flue gas with zero heating value plus 27 per cent devolatilization products. By reducing the flow and extracting the volatile matter driven off by the big heat accumulator underground, it is always possible to produce temporarily a more valuable gas but not at a continuous and steady rate.

It makes no difference if we assume that the fixed carbon is gasified in the reduction zone and these gases are more or less completely burned by excess oxygen; or as an alternative interpretation, if we neglect this stratification effect and trace the gas analysis back to the

[1] Numbers in parentheses indicate references at end of article.

* Since this article was prepared the author has become associated with Battelle Memorial Institute, Columbus, Ohio.

low reaction temperature. The thermal and economical result is deplorably low and means have to be found to control the reactions or the method has to be changed radically.

Comparsion with Gas Producer

When preparing fuel (e.g., coke) for a standard gas producer we select a well-graded material with as little undersize and oversize as possible, and it is well known from experience that the size (or specific surface) offered to the gases is a decisive factor in the reaction rate, expressed as necessary minimum bed height. In investigations made by P. Nicholls at the U. S. Bureau of Mines (3), using coke of 1 to 1.5 in. diameter, the 24-in. deep fuel bed had an external surface (calculated as spheres) of 128 sq. ft, or 0.03014 sq ft per scfh. The active coal face of the underground gasification experiment (1) was about 1152 sq ft, (0.0172 sq ft per scfh), or roughly only half. A more serious fact is the ratio of heat-producing or active surface to heat-loosing surfaces. In Nicholls' experiments, despite the small size of this experimental reactor (20 in.), the ratio of coke surface to external cooling surface was about 12; in a commercial size gas producer of 10 ft diameter the ratio would increase to 73. The underground gasification with its wide and long-stretched channels loosing heat through floor, roof and walls, has a ratio of only 0.03. This is roughly a 400 times larger relative cooling surface than Nicholls' reactor and 2400 times larger than a standard gas producer using graded fuel. Even considering the insulating effect of the rock or the limited heat flow through the walls (depending upon the type of coal, rock, moisture content, etc.) the total heat leakage is still considerable. If the temperatures are kept high by secondary combustion, the heat loss during the travel of the gas through the channel will decrease the "reaction temperature" or "heat balance temperature" to such an extent that, as a final result, no CO (or H_2) will be produced by gasification of fixed carbon and all the combustible constituents in the product gas must come from the volatile matter of the coal, preferentially from those zones where the oxygen content is diminished or the gas temperature lowered enough not to ignite and burn these gases.

Effect of Physical Conditions

Considering the physical mechanism of the gasification process, it is well known from studies of fixed beds, as well as fluid beds or gasification in suspension, that the "physical reaction resistance" has an overwhelming influence. In other words, the rate of gasification is first of all dependent upon the velocity with which the reacting gases (O_2, CO_2, H_2O) can be brought into contact with the surface of the carbon. The voids in a standard fuel bed are small and of a distorted shape; as a consequence of which high turbulence, a constant change in flow direction, and impingement of the solid surfaces is maintained. This results in excellent heat and mass transfer.

On the other hand, the flow channel of an underground gasification plant is wide and generally not completely surrounded by coal. In time with coal consumption proceeding, the shape and width of the channel becomes out of control. Roof melting, falling down, or caving in may partly close the original cross-section but open new cracks and channels, even some which are not in contact with the coal seam at all. In this wide channel the flow is slow and more or less laminar. The mass exchange from the center to the wall takes a long time and causes the long stretch of the generator with all its drawbacks. From Schiegler's experiments on the mixing of parallel gas streams (4) the mixing length may be estimated less than 0.05 to 0.02 of the length in flow direction, which means that a width or mixing length of 1.5 ft will have a necessary oxidation zone of 30 to 75 ft. In the Gorgas experiment the oxygen disappeared from the gas sample at about 30 to 40 per cent of the 354-ft-long gas path, corresponding to an oxidation zone of 100 to 140 ft, but the beginning of the zone is difficult to determine exactly. There are two explanations for the continuous deterioration of the gas quality: Secondary combustion (by oxygen not showing up in the gas samples because they may not be representative samples of the whole cross area), or the shifting of the gas analysis to higher CO_2 and lower CO content under formation of carbon (soot), according to the falling temperatures caused by the exorbitant heat losses.

In view of the foregoing it is not surprising that this way of gasifying coal underground as practiced in Russia, the United States, Belgium, and Italy did not come up to anticipations. This does not mean that these experiments do not have their merits or have added to our knowledge and experience; but new points of view and possibly entirely new steps must be taken in order to succeed.

First let us consider whether means to improve conventional gas producers are applicable to underground gasification. How could such a gas producer be improved if its reaction temperature is too low or its heat loss too high?

An increase in temperature in a gas producer can be achieved by (1) increasing the heat input by preheating the blast as high as admissible, (2) increasing the throughput (limited by carryover losses), (3) using finer sizes or bigger units (limited by pressure drop and mechanical operability).

There is no choice as to the size of the fuel below ground. The size of the channels or bore holes can be selected to a certain extent. Small horizontal bore holes in the coal seam surrounded entirely by coal would offer certain, although not decisive, advantages; but the growth and change of shape of size during the process of gasification is out of our control. The use of smaller size bore holes could be accompanied by the application of higher air and gas velocities. An uncertain factor is the amount of coal losses if smaller holes are used.

Preheating the blast is a very effective means in above-ground practice but difficult to apply below ground. In commercial plants the length or depth to which the blast travels before it reaches the coal seam would be much greater than in the experimental pilot plants where gasification has been carried on under a small cover or in outcropping coal seams. Most of the preheat would be dissipated before the coal is reached. Therefore, one might consider installation of a heater below ground to be supplied from above ground. The easiest, although most expensive, way would be an electrical heater. Electricity or electrical heat also has been used for

devolatilization of coal, oil shale, and oil sand by Ljungström (5), Jäppelt, and Sarapuu (2). It offers some advantages in the shale and oil industry.

As a possibility to increase the reacting surface of the coal, to shorten the length of the oxidation zone, and to avoid excessive after-burning, the introduction of pulverized coal or coal dust might be considered. However, the result, as concerns gas quality, is still questionable, because pulverized coal gasification under the prevailing conditions would deliver a gas of poor quality. To achieve a tolerable result, extremely high preheating or a gasification under pressure would be necessary. Both measures are difficult to apply underground.

Alternate Means Suggested

A suggested way out of these major difficulties is to employ a completely different process. The physical and thermal handicap may be overcome by making use only of the primary reaction of the gasification of carbon, using inhibitors to prevent the secondary reactions. Dufraisse (6), Arthur (7) and others have shown that secondary reactions could be brought about by 1 per cent Cl_2, PCl_3, 0.1–0.2 per cent $POCl_3$ or CCl_4. Some combustion experiments of coke breeze with air and oxygen with and without CCl_4 are shown in Table 1. They confirm the findings of the previous investigators. It was of special interest to observe that burning of carbon with oxygen in a tube, heated externally to 1600 F, did not show the slightest trace of ash softening or melting. The reactions

$$C + 0.5\,O_2 - 29{,}400 \text{ kcal/kmol} = CO \quad (1)$$
$$C + O_2 - 97{,}000 \text{ kcal/kmol} = CO_2 \quad (2)$$

differ widely in available heat, reaction (2) yielding about 3.3 times more heat than reaction (1).

TABLE 1—COMBUSTION OF COKE BREEZE WITH AIR AND OXYGEN AT 1600 F WITH CCl_4 INHIBITOR

	(1) Air	(2) Air + CCl_4	(3) O_2 + CCl_4
CCl_4, vol %	....	0.11	0.23
Gas analysis:			
% CO_2	17.4	3.7	21.6
% CO	12.0	25.9	76.2
% A + N_2	69.8	69.9	1.7
% H_2	0.5	0.3	0.2
% C_2- C_4-	0.3	0.2	0.3
	100.0	100.0	100.0
CO: CO_2-ratio	0.69	7.00	3.53

The removal of CCl_4 by condensation is impossible. Cooling to minus 40 deg still leaves 0.29 per cent volatile, or enough to render the gas incombustible. Removal by adsorption (with charcoal) seems practical but a loss of other gas constituents is involved, and it is doubtful if CCl_4 recovery would be effective enough to transfer this method (so far used for reaction studies) to commercial-scale plants. The presence of steam or hydrogen nullifies the inhibitor effect. This possibility, meanwhile, displays some very attractive features and the search for other less expensive, practically applicable, and easily recoverable inhibitors seems to be worth while.

If the "stream method" fails, why not return to other more successful methods of underground gasification, although they are no longer a gasification *in situ* and do not eliminate standard mining operations? In the so-called "chamber method" a "generator" was caved out and filled with broken coal by hand packing. This represents even more labor underground than ordinary coal working. The present status of our knowledge and development of gas production, however, offers the possibility of building gas producers for fine fuels (caking or noncaking) with much higher rates than present-day standards. These could be located underground and completely mechanized to minimize attendance, and to allow remote control. Using fine coal means that possibly fast cutting machinery could be used to increase mining production and to ease the coal-handling problem. At least hoisting of the coal above ground, coal preparation and ash disposal above ground are eliminated, and thus contribute to the lower gas production cost. Capacities, yields and gas quality are entirely under control of the operator.

Summary

Duplication of the Russian underground coal gasification experiments have confirmed the still unsatisfactory results of these earlier experiments in so far as calorific values of the gas is concerned. The quality of the gas corresponds to a process in which all of the fixed carbon and part of the volatile matter are burned to a flue gas with zero calorific value, and only the remaining volatile matter constitutes the heating value of the final product.

Possibilities to improve the method are discussed, notably preheating of the blast near the entrance into the coal seam and the use of inhibitors to prevent secondary combustion.

Furthermore, two entirely different approaches to the problem are possible. One would involve heat production underground with means to utilize the heat for power production either by underground steam boilers or gas turbines located at the gas exit duct. Burning of coal underground for heat production would allow, to a limited extent, water gas production by alternative steam blow. The other method (not eliminating standard mining operations) suggests a high-rated and completely mechanized type of gas producer below ground which at least saves part of the mining and ash handling cost and enables the production of gas of any desired quality at a lower price than above ground.

References

(1) Dowd, James J., Elder, James L., Capp, J. P. and Cohen, Paul: Experiment in Underground Gasification of Coal, Gorgas, Ala., *U. S. Bureau of Mines, Rept. Invest. 4164*, Aug. 1947.

(2) Private communication by E. Sarapuu.

(3) Nicholls, P.: Underfeed Combustion, Effect of Preheat, and Distribution of Ash in Fuel Beds, *U. S. Bureau of Mines, Bull. 378*, 1934.

(4) Schiegler, L.: Der Strömungsvorgang in der Brennkammer von Rostfeuerungen. Ein Beitrag zur Berechnung der Strömungsvorgänge auf Grund von Modellversuchen. *Z. Ver. deut. Ing.*, **82**, Nr. 29, 849–855 (1938).

(5) *Från Departement och Nämnder*, **3**, Nr. 20, 1–6, abstracted in *Feuerungstechn.*, **30**, Nr. 7, 165 (1942). Schjånberg, E.: "Production of Shale Oil in Sweden," World Power Conference, *Trans. Fuel Economy Conf.*, The Hague, *II*, Sect. A3, Pap. Nr. 4, 530–539 (1947).

(6) Dufraisse, Charles, and Horclois, Raymond: "Application de l'effet antioxygène au problème de la lutte contre l'incendie Catalyse négative de l'ignition du charbon," *Compt. rend.*, **152**, 564–566 (1931). Dufraisse, Charles, and Vieillefosse, Roger: "Application de l'effet antioxygène au problème de la lutte contre l'incendie. Extinction de la braise en présence d'oxygène," *ibid.*, **154**, 2068–2070 (1932).

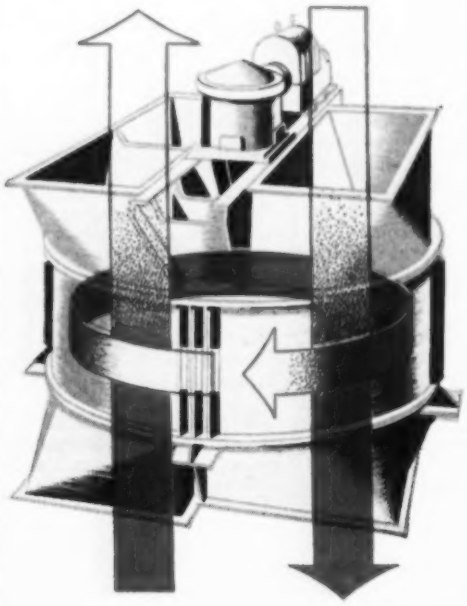
(7) Arthur, J. R.: "Combustion of Carbon," *Nature*, **157**, No. 3996, 732–733 (1946). Arthur, J. R., Bangham, D. H. and Thring, M. W.: "Combustion in Fuel Beds," *J. Soc. Chem. Ind.*, **68**, No. 1, 1–6 (1949).

Fact File on Preheat

No. 6

Cheaper grades of fuel can be used with the Ljungstrom air preheater. For in the Ljungstrom regenerative design heat does not pass through the metal. The elements therefore operate at a higher temperature . . . approximately a mean between the air and gas temperature. This permits safe operation at high recovery rates even with low grade or definitely corrosive fuels.

LJUNGSTROM



The Ljungstrom Air Preheater is a compact gas-to-air or gas-to-gas heat exchanger, operating on a continuous regenerative counterflow basis. Hundreds of leading power plants and other special applications confirm its high level of heat recovery and long-term low maintenance service.

THE

AIR PREHEATER CORPORATION

60 EAST 42ND STREET · NEW YORK 17, N. Y.

Plant: Wellsville, N. Y. 2879

Corrosion Fatigue Cracking in Steam Piping

Digest of a report issued by the British Electricity Authority giving results of an investigation into the causes of corrosion fatigue cracking in a number of British power stations. Such cracking occurred in steam receivers and their connections, spray-type desuperheaters, feed connections to drums and in steam piping.

BECAUSE of the occurrence of serious cracking of steam piping in a number of British power stations, the British Electricity Authority formed a committee to investigate the causes and make recommendations. On this committee were representatives of generating stations, insurance companies, equipment manufacturers and the Department of Scientific and Industrial Research. Its report has just been released and contains, in part and substance, the following observations.

Failure by fatigue was distinguished from that by corrosion fatigue.

In fatigue failure cracks in the metal are set up by fluctuating stress caused by repeated bending, vibration, or alternating compression and tension. Fine cracks may develop in slip planes or slip bands where the stress is highest and may propagate along the slip planes of the grains. These will be transgranular cracks with no apparent deformation. The resistance of the material to the inception and propagation of fatigue cracking is referred to as its *endurance*. Contributing causes are sharp changes of section and surface defects.

Corrosion fatigue, on the other hand, occurs when the endurance of the metal has been lowered by the action of a liquid which wets the surface and attacks the material. Whether or not the liquid produces noticeably active chemical attack, fatigue failure will occur at a lower stress or after a smaller number of stress reversals. Wetting, even with pure distilled water, produces an appreciable lowering of the endurance of steel; and if the water contains dissolved gases or solids that produce a slight continuous attack on the steel, the endurance may be impaired seriously. Fatigue and corrosion appear to act simultaneously and are able to accelerate each other, the corrosive attack being accentuated by continuous rupturing of the protective oxide film.

Corrosion fatigue cracks are also transgranular, but they are usually more nearly straight than those produced by fatigue without corrosion. Corrosion tends to widen the crack at its mouth and give rise to a distinctive pear-pointed form, as indicated in Fig. 1. Or, where the corrosion is very active, pits may form and become stress raisers. However, in many cases of failure by corrosion fatigue there has been no visible evidence of active corrosion or chemical action other than the normal uniform oxide coating.

Failures in steam piping and steam receivers caused by corrosion fatigue may result from mechanical or thermal stresses. The former may be set up by bending loads, vibration or restriction to normal expansion. The latter arises from repeated cooling of an area of the metal either by condensate or by water introduced for desuperheating.

With a saturated steam system, both the condensate and the metal surface will be at or near the saturation temperature; but with superheated steam, although any water present cannot be at a temperature in excess of that of saturated steam, the metal temperature will usually be much higher. Hence if the water is brought in contact with the metal surface, a rapid reduction in temperature of the metal may occur locally because of the high rate of heat transfer and because a large amount of heat must be extracted from the metal surface to supply the latent heat of vaporization to the liquid. Cooling of a small area in this way causes a high local contraction and an area of high tension. The stress may be high enough to cause fatigue, but when the endurance is lowered by the presence of water, cracking such as shown in Fig. 2 is much more likely to develop.

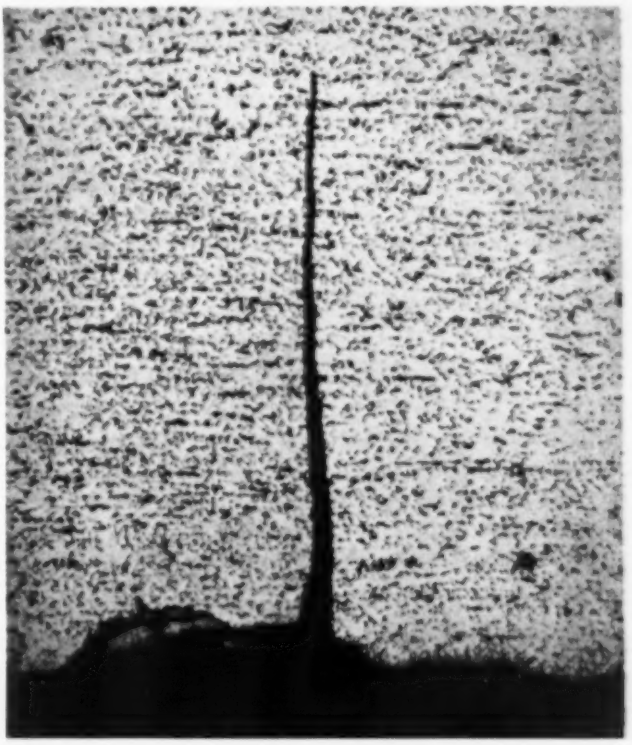


Fig. 1—Photomicrograph of corrosion fatigue crack × 100

The more massive the part wetted, the more likely are high local stresses to be set up.

Water or condensate need not always wet the surface, for it may exist in a spheroidal state as globules supported and insulated by a layer of steam. In this form it is potentially dangerous as it may be projected at high velocity against the surface, due to a change in direction of flow, or come in contact with the sharp edge of a branch or drain, and thus wet the surface. Furthermore, wetting is facilitated if the surface is rough or deposits are adhering to it.

Locations Where Failure May Be Expected

It is often found that the preponderant flow of steam in a receiver is in one direction and that surface cracking has occurred in the line of flow from a branch opening which has been discharging condensate.

In steam piping, cracking frequently occurs in or near a branch connection for the same reason as in a receiver; that is, steam condenses in a stagnant leg and the condensate either falls continuously or collects and is subsequently ejected when steam flow in the line commences, thus quenching the hotter metal of the main pipe. Also because the rate of heat transfer between superheated steam and water at saturation temperature is relatively low, water can flow intermittently along the bottom of a pipe carrying superheated steam. Long lengths of pipe have been found to be cracked under these conditions.

The bodies of spray-type desuperheaters, or the steam piping following them, may develop cracks if not properly protected, or if the method of introducing the water is such that the surfaces are intermittently quenched.

The temperature of a boiler drum is normally that corresponding to the saturated steam pressure. Where relatively cool feedwater is introduced intermittently, perhaps due to a hunting feed regulator, and allowed to make contact with the drum wall, corrosion fatigue cracking may take place.

Detection

As a rule, the only external sign of corrosion fatigue is leakage of steam through a crack that has penetrated the wall of a pipe or receiver; although occasionally a part suffering from corrosion fatigue cracking on the inside surface is observed to bulge outward, owing to the combined effects of stress and the increased volume of corrosion products in the cracks. It may sometimes be indicated by parallel circumferential or longitudinal markings, or both; by cracks radiating from a small opening for a gage connection; or it may be associated with pitting. In fact, corrosion fatigue cracking is often not easy to detect and may be very difficult to see owing to the fineness of the cracks.

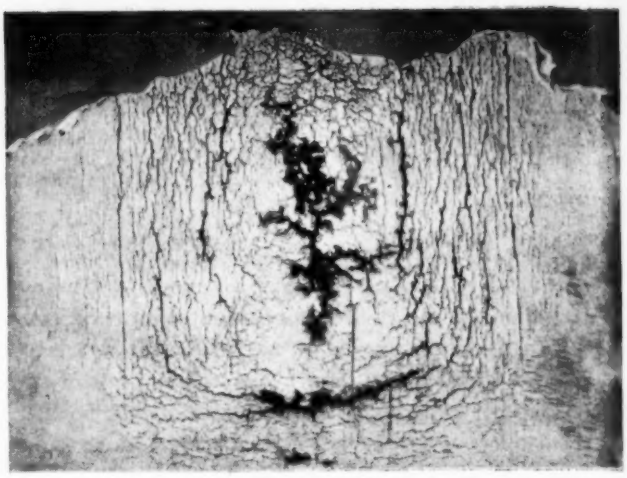


Fig. 3—Corrosion fatigue crack in a receiver branch

Sometimes cracking is preceded by the appearance of marks on the oxide scale surface in a pattern resembling Lüders lines. In general, any area that shows persistent watermarks is liable to develop corrosion fatigue cracking and should be examined carefully.

Avoidance of Cracking

The Committee, as a result of examining plants where failures occurred, recommends: (1) that abnormally high stresses due to thermal expansion or structural loads be avoided; (2) the layout should avoid, as far as possible, the formation of condensate during operation or when shut down; and (3) that provision be made for condensate, whether formed continuously or occasionally, to be removed from the system without contacting massive or vital parts of the plant. It should be handled by equipment that can be easily replaced.

Fig. 2—Typical corrosion fatigue cracking in steam pipe

COMBUSTION ENGINEERING

for power plant men . . . Become a trained combustion Engineer the easy HAYS way. Firemen, engineers, fuel and equipment men, etc., can earn bigger pay by becoming a Hays trained combustion engineer. Many employers recognize a HAYS-TRAINED engineer as a better man. Just a little of your spare time required for the simple, easy-reading Hays Home Study Course. Hundreds of others have made better jobs for themselves through Hays training. So can YOU.

Approved for GI. *Write today for free book.*

Our 30th year. **HAYS SCHOOL OF COMBUSTION**

Dept. 512 **430 N. Michigan Ave., Chicago 11, Ill.**

Dept. 512
HAYS SCHOOL OF COMBUSTION
430 N. Michigan Ave., Chicago 11, Ill.

Name_____

Address_____

City_____ State_____

Company Name_____

STEAM SAMPLING METHOD

FOLLOWING is a digest of some of the more important provisions in the tentative method of sampling steam which has lately been accepted by the A.S.T.M., under designation D-1066–49T, for use pending its formal adoption as standard. It covers the sampling of either saturated or superheated steam flowing in a pipe or conduit at a pressure above that of the atmosphere.

Impurities in steam may be solid, liquid or gaseous. The first two consist of dusts and mists mechanically entrained in the steam. They are of higher density than the steam and may not be uniformly dispersed. Gaseous impurities may consist of carbon dioxide, oxygen, ammonia, hydrogen and other gases introduced by the feed-

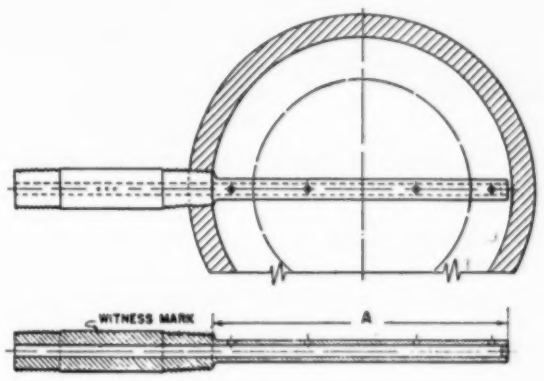


Fig. 1—Recommended form of sampling nozzle

water or generated within the boiler. They may also include the vapor phase of substances present in the boiler water and are molecularly dispersed in the steam.

An important requirement in the sampling of fluid streams carrying particles in suspension is that the velocity entering the ports of the sampling nozzle shall be the same as that in the stream being sampled; also, that each port of a multiport sampling nozzle withdraw a portion of the main stream equivalent to the area of the portion of pipe or duct in which it is located. The velocity of sample flow within the nozzle should be kept low in order to reduce the pressure drop along the nozzle and to provide, as closely as possible, an equal pressure drop across each sampling port. For this reason the total area of sampling ports should not exceed two-thirds the inside cross-sectional area of the nozzle.

Required Apparatus

The apparatus consists of a steam sampling nozzle, the necessary piping, valves and fittings; and, when required, a sample condenser and cooler. The recommended form of sampling nozzle is shown in Fig. 1 which extends to within $^1/_4$ in. of the opposite wall and has 4, 6 or 8 ports according to the inside diameter of the pipe of 2 to 6 in., over 6 to 12 in., and over 12 in., respectively. It will be noted that the nozzle is tapped into the pipe. Each port represents an equal area of pipe section and their size is such that the ratio of their total area to that of the pipe is equal to the ratio of rate of sample flow to rate of stream flow. A sampling nozzle for use in small tubes carrying high pressure is also provided. 2. Care should be taken that the nozzle ports face upstream.

Fig. 2 is a chart showing the approximate rates of flow for steam through different size calorimeter orifices at various pressures, and Fig. 3 shows the saturated steam flow through pipes of different inside diameters at various pressures.

When the sample is analyzed for moisture content by means of throttling or separating calorimeters, the rate of flow is fixed by the characteristics of the calorimeter. When the steam is to be condensed or cooled for specific conductance measurements, or for the evaporative method of analysis, the sampling nozzle may be designed for maximum rate of stream flow and the rate of sample flow may be adjusted for lower rates of flow.

The shortest possible connection shall be used between the sampling nozzle and the calorimeter or cooling coil.

For use with a calorimeter the valves, connecting piping and fittings are of carbon steel; but when the sample is to be condensed or cooled, the connecting piping and fittings must be of stainless steel. A tubular heat-exchanger may be used.

The sampling nozzle shall be located after a run of straight pipe of a length equal to at least ten diameters, with preference for downward flow in a vertical pipe.

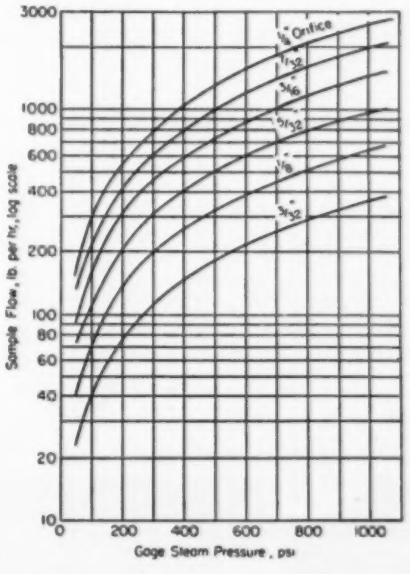


Fig. 2—Rates of steam flow through calorimeter orifices at different pressures

Moreover, it shall not be located immediately after valves or bends. When a boiler is arranged with multiple tubular connections from the drum to a superheater header, samples shall be taken from selected tubes spaced across the width of the drum at no greater than 5-ft intervals; or they may be taken at the inlet header of the superheater. For long headers samplers should be installed at each end of the header.

When a new sample line is being put into service, it is necessary to flow steam and condensate through it for 24 hr before samples are collected. Also before a sampling period, steam should be blown through the sample to remove any material that may have been deposited in it.

When samples of condensate are collected for evaporative analysis, the flasks or other containers should

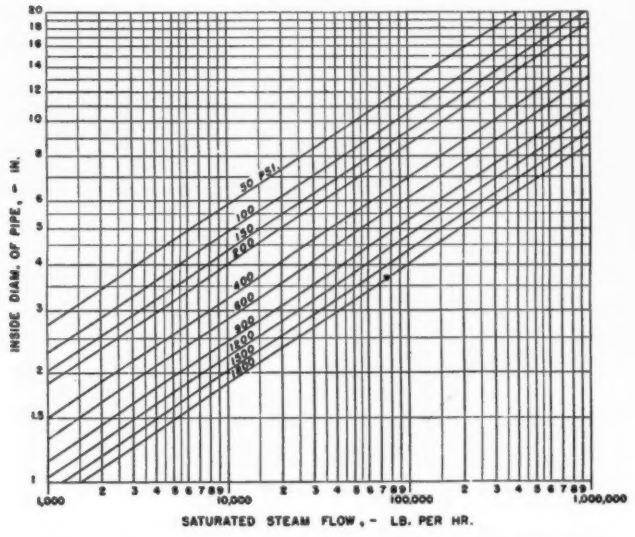


Fig. 3—Approximate rates of flow for saturated steam for different internal pipe diameters at different pressures

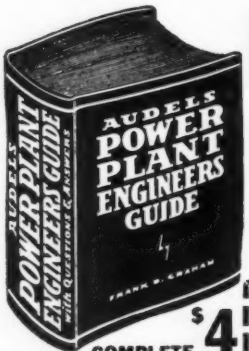
be meticulously cleaned before using, and the samples should be analyzed as soon as possible after they have been collected.

The sampling rate is determined by the relation:

$$f = a/A \times F$$

where f and F are the sample flow rate and steam flow rate, respectively, and a/A is the ratio of total port area to pipe area.

Copies of the complete "Tentative Method of Sampling Steam" may be had from the American Society of Testing Materials, 1916 Race St., Philadelphia 3, Pa.



$4 COMPLETE

PAY ONLY $1 A MO.

Get this information for Yourself. Mail Coupon Today. No Obligation Unless Satisfied. ASK TO SEE IT.

ENGINEERS INFORMATION ★ ★ ★

QUESTIONS and ANSWERS

JUST OUT! Audels Power Plant Engineers Guide. A complete Steam Engineers Library covering Theory, Construction & Operation of Power House Machinery including Steam Boilers, Engines, Turbines, Auxiliary Equipment, etc. 65 chapters, 1500 Pages, over 1700 Illustrations. 1001 Facts, Figures and Calculations for all Engineers, Firemen, Water Tenders, Oilers, Operators, Repairmen and Applicants for Engineer's License.

FREE TRIAL!

AUDEL, Publishers, 49 W. 23 St., New York 10

MAIL AUDELS POWER PLANT ENGINEERS GUIDE for free examination. If O.K. I will send you $1 in 7 days; then remit $1 monthly until price of $4 is paid. Otherwise I will return it.

Name_____

Address_____

Occupation_____

Employed by_____ COM

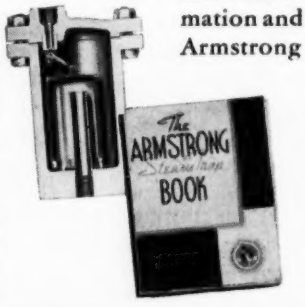
ARMSTRONG "Power Plant" STEAM TRAPS

. . . Meet All Requirements for Modern High Pressure, High Temperature Service

ANY engineer responsible for the design or operation of modern, high pressure, high temperature steam plants can safely provide the benefits of completely automatic condensate drainage by specifying Armstrong Forged Steel Steam Traps. Their inherently trouble-free design plus highest quality materials and workmanship assure safety and dependable performance. There is no chance of failure to open when condensate fills the trap and no steam loss under no-load conditions. The extensive line includes traps to meet any pressure, temperature or capacity requirements.

Armstrong Forged Steel Traps are also ideally suited to low and medium pressure service where "all-steel" installations are desired.

Where quality, safety and dependability come first, specify ARMSTRONG, the "standard" in many high pressure plants throughout the world. For more complete information and prices, consult your nearby Armstrong Representative or write:



• SEND FOR the 36-page ARMSTRONG STEAM TRAP BOOK for complete data on sizes, capacities, selection, installation and maintenance of Forged Steel and Cast Semi-Steel Steam Traps.

ARMSTRONG MACHINE WORKS
814 Maple St., Three Rivers, Mich.

Facts and Figures

The allowable stress for carbon steel decreases rapidly above a temperature of 700 F.

•

In spreader stoker firing the carryover increases nearly as the cube of the firing rate.

•

The heating value of a fuel oil can be estimated closely from knowledge of its A.P.I. gravity.

•

Dissolved solids are defined as the dried residue from evaporation of the filtrate after the suspended solids have been separated by filtration.

•

The heat loss due to combustible carbon in black smoke is very small compared with that due to carbon monoxide, hydrogen and methane in the chimney gases.

•

One of the chief factors in water treatment by demineralization is the selection of a cation resin that will permit operation without sodium leakage.

•

Since draft is proportional to barometric pressure, stacks at higher altitudes, for a given draft, must be higher than those located at or near sea level.

•

Waste heat from Battersea Power Station, London, will be employed to heat a group of apartments across the Thames River. For this purpose an accumulator has been erected adjacent to the apartments.

•

Grindability of a coal is a measure of the ease with which it may be reduced to a given size of fineness and has little bearing on the wear of pulverizer parts which is governed by the abrasiveness and hardness of the coal.

•

Claimed to be the world's largest pumps, six Byron Jackson units are now building on the Pacific Coast to lift water from the Columbia River, at Grand Coulee, to irrigate a million acres of land. Each is capable of handling 720,000 gpm against a head of 300 ft and will be driven by a 65,000-hp electric motor.

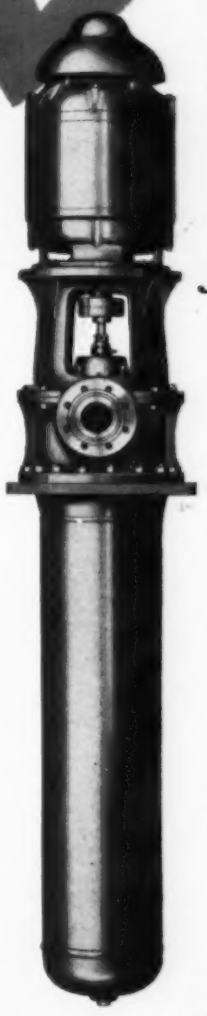
•

In chemical cleaning of steam generating and heat-transfer equipment it is very necessary that confined spaces be adequately vented, inasmuch as hydrochloric acid reacts with iron to liberate some hydrogen, despite the use of inhibitors, and this when mixed with oxygen in a confined space forms an explosive mixture that will ignite easily.

Is your problem

LIMITED SPACE * ?
LIMITED N.P.S.H. *

Check



Pacific
TYPE WY
VERTICAL CENTRIFUGAL
PUMPS
for:

CONDENSATE
BOILER FEED
HEATER DRIPS
HOT WATER CIRCULATION

SPACE REQUIRED—
for 6500 G.P.M.—
only 62" x 56"!

N.P.S.H. REQUIRED—
only one foot or less
at the suction nozzle!

Write for Bulletin 105 showing cross sections and typical installations.

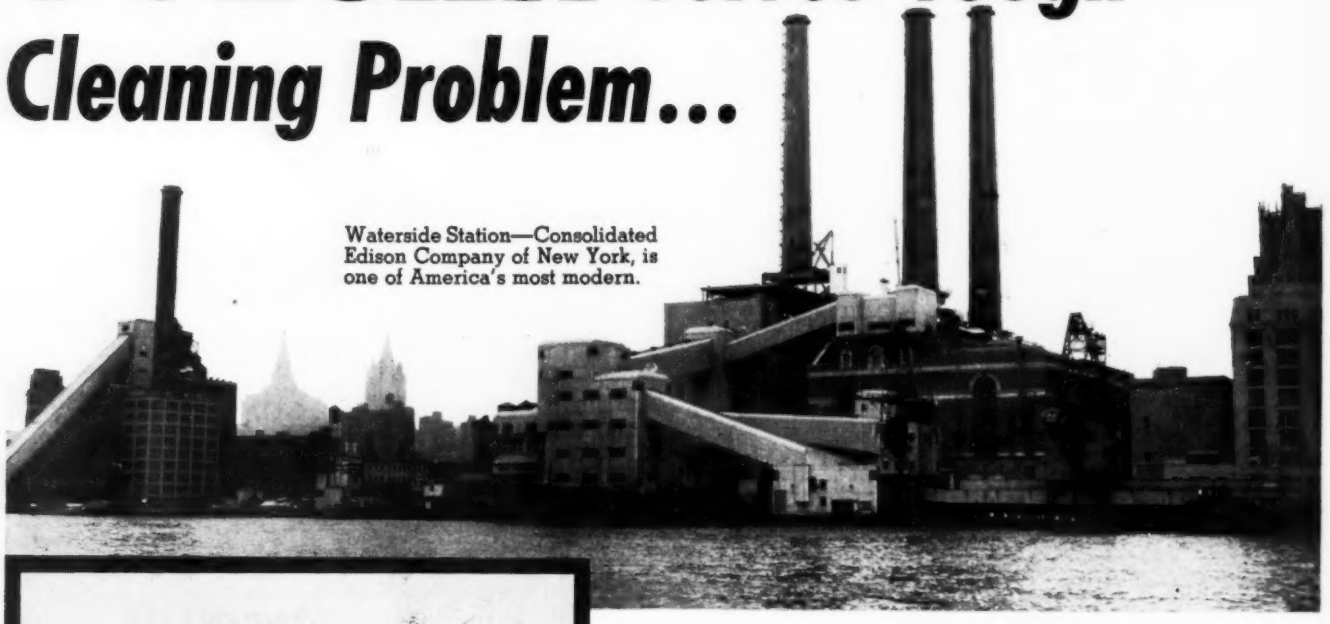
PACIFIC
Precision **Built**
PUMPS

PACIFIC PUMPS 25th ANNIVERSARY

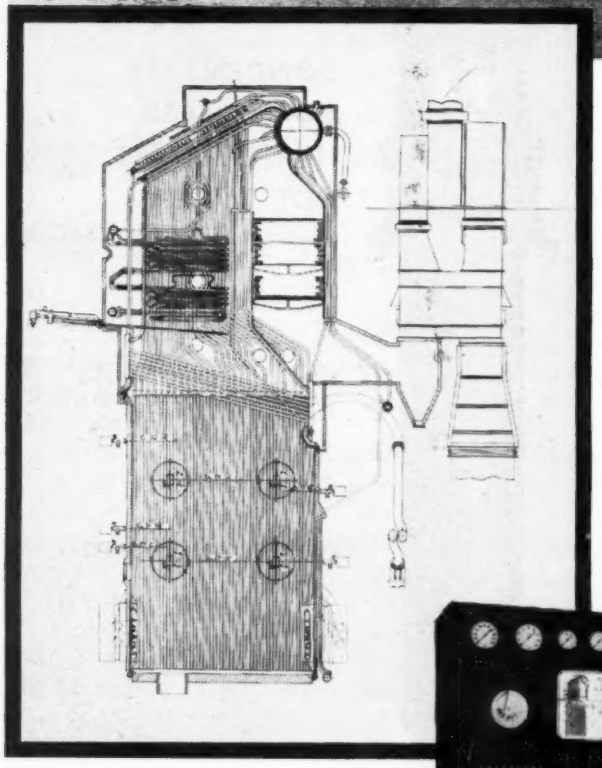
PACIFIC PUMPS INC., *Huntington Park, California*
One of the Dresser Industries
Export Office: Chanin Bldg., 122 E. 42nd St., New York
Offices in All Principal Cities

V-3

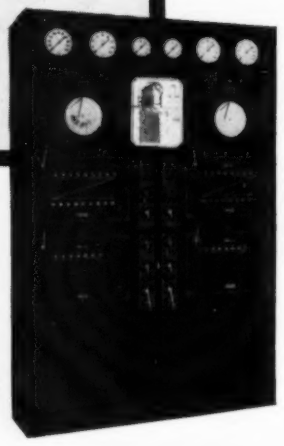
VULCAN *Solves Tough Cleaning Problem...*



Waterside Station—Consolidated Edison Company of New York, is one of America's most modern.



Side elevation, one of four 500,000-pounds-per-hour boilers at Waterside Station No. 2.



Central Vulcan Control Panel for Boilers 41 and 42 at Waterside Station No. 2. Panel for Boilers 51 and 52 is identical.

for the WORLD'S LARGEST PUBLIC UTILITY

Space limitations at Waterside Station No. 2 of Consolidated Edison Company of New York, world's largest public utility, were effectively overcome by Vulcan Automatic Sequential Soot Blowers. Each of the four 500,000-pounds-per-hour boilers has twenty RW-1 Deslaggers, plus five T-2 Long Retractables paralleling boiler tubes. A tough problem, yes—but all boilers are kept clean without hand lancing, thanks to Vulcan engineering.

•

Vulcan also serves Consolidated Edison at Waterside No. 1, Hunt's Point and East River—and has been selected for Hudson Avenue's new 1,300,000-pounds-per-hour unit.

VULCAN SOOT BLOWER CORPORATION
DUBOIS, PENNSYLVANIA
Division of
CONTINENTAL FOUNDRY & MACHINE COMPANY

VULCAN *Automatic Soot* **BLOWERS**

Atomic Energy Power Prospects

Many talks and papers have been presented by competent authorities on the prospects for achieving nuclear power on a commercial scale. There seems to be general agreement concerning the obstacles that must be overcome and that some years must elapse before such a power plant is in commercial operation. However, because of certain as yet unsolved problems, the economics are open to a wide variation in predictions.

A most lucid review of the subject was contained in an address by Philip Sporn before the Annual Meeting of the National Coal Association at New York, on October 7. Mr. Sporn, who is president of the American Gas and Electric Service Corporation, is also chairman of a committee charged with cooperation between the electric power industry and the Atomic Energy Commission. As such, his views have special significance. Following is a digest of some of his remarks:

At present there is no known basis for believing that direct conversion of fissionable material into electric energy can be attained. Instead, uranium 235, or plutonium, will be burned as fuel by supplying neutrons. The products of combustion will be heat and hot gases, the former being absorbed and the latter cooled by a coolant which will be employed to produce steam for a turbine or to heat gas for a gas turbine. The cooled gases will be discharged through a stack to the atmosphere. A by-product will be ash consisting of fission fragments. The machine in which this operation will be carried on is called a *nuclear reactor*.

However, both the ash and the gases emitted from a nuclear reactor are highly radioactive and thus present complex problems and hazards for which satisfactory solutions are not yet known.

No one can yet tell just what materials are needed or available to meet the peculiar requirements of a nuclear reactor for such use. The material must have a reasonably low neutron absorption, so as not to "quench the fire"; yet it must be able to withstand untried conditions of temperature and rates of heat transfer. Furthermore, it must resist essential change despite bombardment of neutrons, gamma rays, beta rays, and other products of the fission process.

A most vital factor in the economics of nuclear power generation is the "breeder." Breeding is the process (theoretically attainable, but actually still to be demonstrated) by which there is produced more fissionable material than is consumed in the operation of the reactor. The major obstacles standing in the way of developing breeder reactors are of an engineering nature and are concerned with basic conflicting requirements for high neutron economy and high power output for a given material investment. There are also chemical problems associated with the treatment of partly depleted fuel.

In the fiscal year 1948, the Atomic Energy Commission entered into obligations amounting to 54 million dollars for reactor development; the figure for 1949 is 61 million and over 100 million was authorized by Congress for 1950. But the reactors that are to be constructed under this program are designed for experimental purposes only and are not intended to be capable of supplying power. Reactors other than those planned for the next few years will have to be built before such results are attainable.

Assuming that the problem of breeding will have been successfully developed, one pound of uranium will be able to do the work of 1500 tons of 13,000-Btu coal, under which conditions the direct fuel cost will be very small. But processing of the fuel will involve elaborate and relatively expensive chemical operations. The capital costs of the chemical plant, the nuclear reactor and the steam and electrical portions of the complete atomic power plant are bound to be the dominating portion of the cost of electric energy at the point of generation. Estimates of capital costs have ranged from $140 to as high as $1000 per kilowatt upon which the depreciation rate would likely be higher than normal, because of the more rapid obsolescence always present in a new technology. However, until the reactor program develops the necessary data, it will not be possible to narrow the range of estimates. Furthermore, the fuel costs cannot be accurately estimated until the breeding phase of the present program is more fully developed.

These two unknown factors constitute the principal barrier to a sound engineering appraisal of the economics of nuclear power at present.

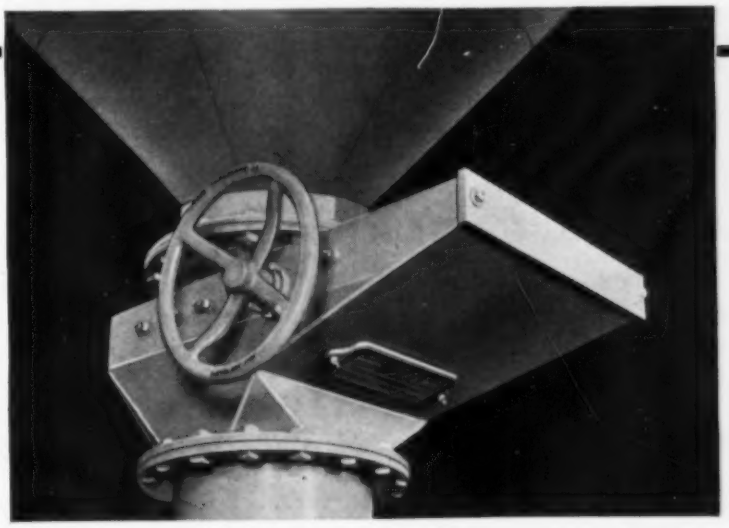
In the event that cheaper electric power can be achieved through use of atomic energy, industries that operate with a high electric energy consumption per worker would benefit most. Such industries are reduction of magnesium and aluminum, refining of copper, production of cement, chlorine and caustic soda, and products produced in an electric furnace.

With the technical problems still to be solved, Mr. Sporn was of the opinion that the purely experimental phase of the program would take from three to five years. Within three to five years thereafter he believed we may have a reactor producing electric power; and four to five years after that (or ten to fifteen years from now) there may be some commercial generation of nuclear power.

New Fiber for Dust Collection*

Recent articles in the public press have mentioned the development by E. I. du Pont de Nemours & Company of a new acrylic fiber designated by the trademark "Orlon." Because of its applicability in cloth filters for the collection of dust,

* The cooperation of Dr. B. S. Farquhar, E. I. du Pont de Nemours & Co., Rayon Dept., Acetate Div., "Orlon" Sales Development, Wilmington, Del., is acknowledged in the preparation of this report.—EDITOR



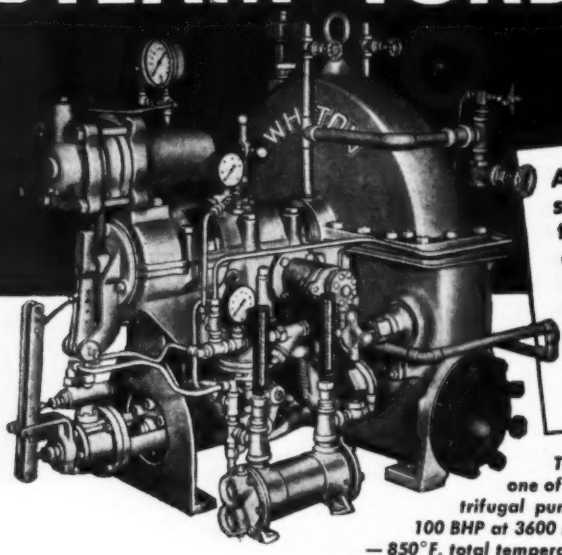
S-E-CO. COAL VALVES open and close with little effort because the gates of these valves are supported on roller bearing rollers and because the shafts are also equipped with roller bearings. Suitable dust seals prevent coal dust and moisture from entering bearings. If you want a coal valve that always rolls easily, a S-E-Co. Valve is your answer.

Write for bulletin.

STOCK ENGINEERING COMPANY
715C Hanna Building ★ Cleveland 15, Ohio

Whiton SOLID STEEL ROTOR

STEAM TURBINES



Available in single stage types up to approximately 1200 HP rating. Center supported frames are available when required.

Turbine shown above is one of 24 ordered to drive centrifugal pumps designed to deliver 100 BHP at 3600 rpm with steam at 850# — 850°F. total temperature exhausting against 42# gauge back pressure.

• SIMPLE DESIGN FOR ACCESSIBILITY

Inlet and exhaust connections are located in lower half of casing which is horizontally split to allow easy access to all internal parts. Rotating unit including bearings and governor head may be removed without disturbing alignment of the unit.

• RUGGED CONSTRUCTION FOR RELIABILITY

Whiton rotors are made from a solid steel forging with semicircular buckets milled in the rim to give strength where it is needed. End thrust is minimized because the path of the steam is always at right angles to the shaft.

• SAFETY DEVICES FOR TROUBLE-FREE OPERATION

Standard equipment includes Constant Speed Governor with V-Ported Governor Valve . . . Emergency Governor with Independent Valve . . . Steel Plate Steam Strainer . . . Two oil rings per bearing supplemented by water cooling . . . Sentinel Type Casing Relief Valve . . . Additional accessories available as required.

THOUSANDS OF SATISFACTORY INSTALLATIONS SINCE 1911

Write for complete information

Whiton 1856

WHITON MACHINE COMPANY

NEW LONDON, CONN., U.S.A.

also makers of Fine Lathe Chucks • Gear Cutting Machines • High Production Milling Machines • Centering Machines

fumes, and smoke, this new material is of interest to engineers in the steam power field.

Orlon is a high-strength yarn manufactured from polyacrylonitrile. It is now in transition from the experimental stage of development to commercial production in a plant which is scheduled to begin operation late in 1950. At present, limited quantities are being sold for market development. Some of the uses to which this material seems particularly well adapted include acid-resistant clothing, anode bags, conveyor aprons, hydraulic and pneumatic filtration, electrical insulation, diaphragm fabric, and rubberized materials for applications in the certain industries.

Among the properties of Orlon acrylic fiber are resistance to degradation by sunlight, outdoor exposure, heat, and many chemicals including mineral acids; excellent dimensional stability to dry and wet cleaning; high flex life; low moisture absorption; high resistance to degradation by microorganisms and insects; excellent bonding to rubbers and resins; good electrical properties; and high melting and sticking temperatures. More specifically, Orlon has a tensile strength above viscose and acetate rayons and close to nylon; exhibits good to excellent resistance to mineral acids, and fair to good resistance to weak alkalis; and is not harmed by common solvents, oils, greases, neutral salts, and some acid salts. The new material has a low specific gravity of 1.17 and filaments have a "dog-bone" cross section.

After being subjected to a temperature of 257 F for a 32-day period, Orlon retained its original strength when tested at room temperature after the yarn had cooled. Its ignition temperature is higher than that of cellulosic fibers, the burning rate being between that of viscose and acetate rayon. When burning yarn the combustion products have been found to be no more toxic than those resulting from the burning of silk or wool under normal atmospheric conditions.

Potential Uses

Orlon acrylic fiber is adapted to use in cloth filters for the collection of dust, fumes, and smoke because of its greater resistance to degradation by elevated temperature exposure and acid components plus the fact that it is a high-strength fiber showing high flex life. It is resistant to outdoor exposure, insects, mildew, and marine organisms.

At the present time dust filter fabrics are being woven in limited amounts by only a few weavers, but this condition will change when commercial yarn production is generally available. Some cloth collector equipment manufacturing companies are undertaking experimental evaluations and limited commercial applications of Orlon in this field. Materials that have been collected to date include carbon black, activated carbon, pigments, food products, resins, coal dust, zinc oxide, lead oxide, and various other metal oxides and metals. Orlon acrylic fiber has been of interest in these cases because of its resistance to acids, its capability of higher temperature operation, and its potentiality for longer cloth life.

Chemical Additives for Coal

PERIODICALLY there appear on the market new discoveries for chemically treating coal to eliminate smoke and clinkers, and remove soot or reduce fuel consumption. Most of these have been investigated by the U. S. Bureau of Mines and found wanting, the findings being published in its Bulletin No. 404. Notwithstanding this, one or two such products have lately been brought out by long-established firms whose excellent reputations warrant consideration of their claims. However, as for the general run of these coal additives, Appalachian Coals, Inc., comments as follows in its October Bulletin:

"Apparently the 'discovery' of these 'miracle' chemicals runs in cycles. There was a cycle of chemical additives to coal in the early '30's; another cycle in the early '40's; and it appears as though we are getting ready for the third cycle in the early '50's. When one company gets into the field with a product, others follow.

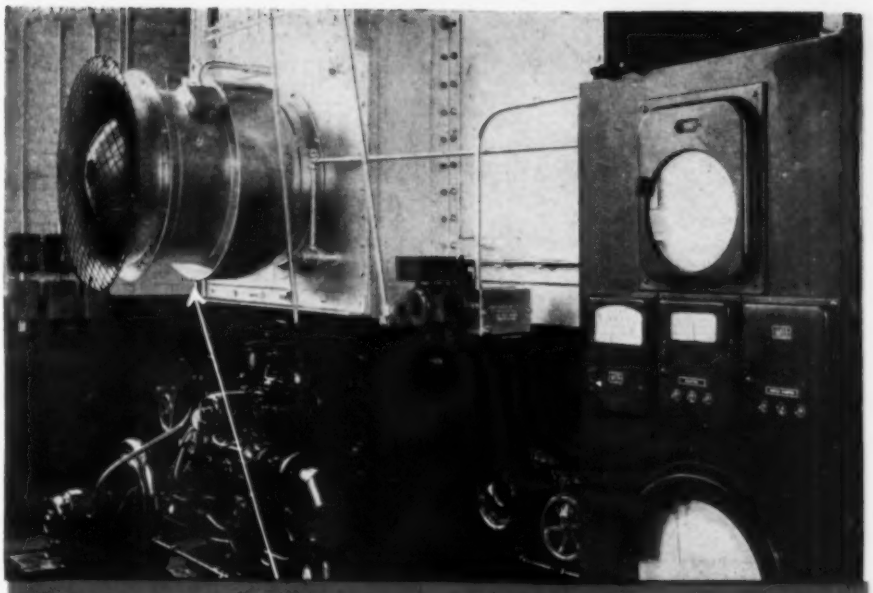
"While many brand names have been used for the various 'miracle' chemicals, either in liquid or solid form, the claims for them all run about the same—that small amounts of the material being advertised, when added to the fuel, will eliminate smoke, remove soot, add enough oxygen to the fire so that the drafts may be cut off, reduce the coal consumption 25 to 50 per cent, and, in some cases, burn up the ash so that only half as much ash will need to be handled. Since emphasis has been put on fly-ash reduction in some city ordinances, 'new discoveries' have been made which are claimed to reduce fly-ash emission to acceptable limits.

"The claim that a chemical will release sufficient oxygen in a fire to materially help oxidize the coal is of course absurd. Potassium permanganate, one of the best oxidizers known, is frequently used as one of the ingredients of these 'fuel savers.' It would, however, take 72 tons of potassium permanganate to furnish sufficient oxygen to burn a ton of coal.

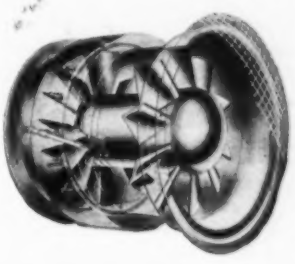
"There have been a number of catalysts on the market which are claimed to increase the reactivity of the coal, but so far none appears to have stood up under impartial tests. Since ash is noncombustible, any claim that ash is 'burned up' is patently absurd. In so far as reducing the fly ash is concerned, added turbulence, if properly applied, will help reduce fly ash, but this can be achieved much more readily by regular air or steam jets. The reactivity of soot is increased to some extent by the addition of ordinary salt or soda ash, but the improvement is minor, and ice cream salt is just as effective.

"Clinkering can be increased by the addition of large amounts of silica, ground glass and a few other things, but as far as it is known no catalytic action can be produced by any known material. The same thing is true of reducing the clinkering or increasing the fusion point of the ash.

"A favorite means of introducing these 'magic' chemicals is through the medium of steam jets. Inasmuch as steam jets alone are quite effective, some of these installations have been fairly successful.



Highest Efficiency—Quiet Operation Combined in Wing Forced Draft Blowers



Phantom view of Wing Axial Flow Blower showing Voltrol Vanes. Note flanged discharge outlet for ease in connection.

Rugged, reliable Wing Axial Flow Forced Draft Blowers are adaptable to any boiler—assure the constant flow of forced draft that means better combustion, lower fuel costs. These compact blowers are characterized by highest head efficiencies (as high as 94%), ease of control, exceptionally quiet operation, and simple, sturdy design. Built-in Wing Voltrol Vanes (capacity regulating dampers) are actuated by an externally balanced lever, and assure the most precise degree of draft control. A reduction in air volume is accompanied by a reduction in horsepower requirements over a wide range. Voltrol Vanes may be adjusted manually, or completely automatic operation may be had by connection to any standard combustion control device. Volume control may also be attained by the use of variable speed motors, which provide ample power for maximum loads, with economy for running loads. Efficient fans are mounted on motor shafts, and the entire unit is sturdily supported inside the cylindrical casing.

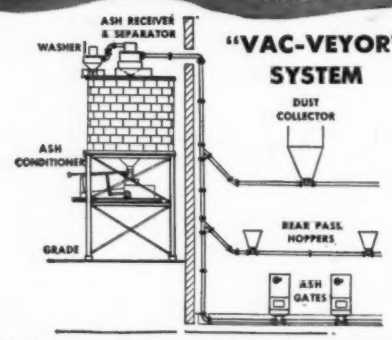
A bulletin containing complete information on Wing Axial Flow Blowers may be had by writing L. J. Wing Mfg. Co.

L. J. Wing Mfg. Co. 54 Seventh Ave., New York 11, N. Y.
Factories: Newark, N. J. and Montreal, Canada

Wing

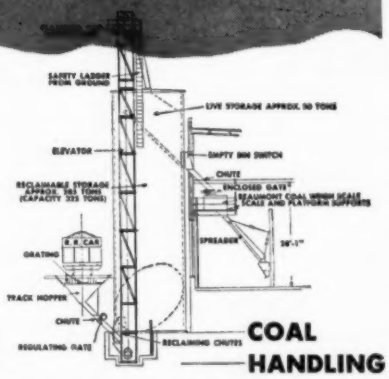
AXIAL FLOW BLOWERS

Profits Saved AT EVERY STAGE . . . WITH BEAUMONT COAL & ASH HANDLING EQUIPMENT



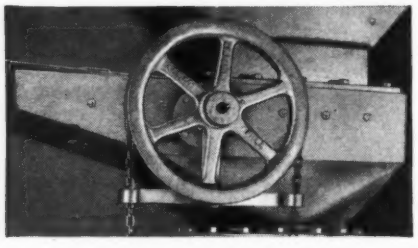
"VAC-VEYOR" SYSTEM

In this system, ashes, siftings, soot and dust are conveyed by pipe from the ash pits, dust collectors, stack, etc., to an ash receiver and separator at the top side of a silo—by means of a vacuum. One man operates the system, keeping your plant cleaner with less labor.



COAL HANDLING

Coal arrives by rail, is dumped into hopper, raised by bucket elevator and discharged either into bunker for immediate use or down chute to yard storage. One operator controls all equipment.



ROLLER BEARING GATE

Incorporating double rack and pinion for granular or powdered materials, these drip-proof self-cleaning gates will not corrode, bend or warp. Material cannot collect in back of gates—these ball bearing gates operate manually or electrically without strain or ramming.

AUTOMATIC WEIGHING SCALE

Accurately weighs coal and similar materials from 1 to 60 tons per hour. Vibrating feeder plate eliminates belts, pulleys and motors. Scale is totally enclosed, dustproof and quiet.

DRAG SCRAPER SYSTEM

Coal is dug evenly with minimum power consumption. Tail blocks can be slung between posts and moved by hand, mechanically moved on I-beam track by tail block car, or suspended from aerial bridge system. One man can operate entire system by remote control.

ASH HOPPERS AND GATES

Steel plate ash hoppers are low cost, rigid, unbreakable, watertight and, when lined with refractory material, resist temperature and erosion. Ash gates are designed for use on stoker and pulverizer ash hoppers where water sealing and draining is essential.

Beaumont engineers design and erect this and associated equipment — ***a complete coal and ash handling system.*** You save in installation as well as in handling. ONE CONTRACT — ONE RESPONSIBILITY — FOR BULK HANDLING SYSTEMS. Write for more information to:

BEAUMONT BIRCH Company

1506 RACE STREET—PHILADELPHIA 2, PENNA.

Designers Manufacturers Erectors BULK MATERIAL HANDLING SYSTEM

However, where a competent and impartial engineer has been allowed to run a test, it has been found that the steam jets alone would have accomplished as much as the jets plus the chemical, or catalyst, as it is now commonly called.

"It is possible that some day a catalyst or other chemical will be discovered which will materially aid the combustion of coal.

"If fly ash is a problem, then it may be necessary to install fly-ash-collector equipment. This equipment can be installed, incidentally, for about twice the cost of a catalytic-jet installation. Then the action is positive and effective. In any case where such jet installations are still on an approval basis, it is suggested having competent engineers run tests on them.

"This discussion has no bearing on the use of oil or chemicals designed merely to allay dust in connection with the handling of coal."

A New Method for Determining Hardness

In a paper before the American Water Works Association on September 16, 1949, J. D. Betz* and C. A. Nall* described a new simple hardness test for water analysis which is said to be more accurate and more rapid than the widely used soap method. It employs a color indicator and, because of its simplicity, accurate results are obtainable by non-skilled personnel.

This new procedure represents a revision of the Biedermann and Schwarzenbach Method and is based on the titration of a water sample with an organic sequestering agent that will form un-ionized complexes with calcium and magnesium. The titration is performed in the presence of an indicator (Erichrome black T) which is red when calcium and magnesium ions are present and blue in their absence. A buffer solution is added prior to the titration to adjust the pH value of the sample to approximately 10.

The Biedermann and Schwarzenbach method employed a non-alcoholic dye indicator solution with an ammonium chloride-ammonium hyroxide buffer, but a sharp color change could not be obtained with calcium alone without deliberately introducing magnesium to obtain the end point. But with the revised indicator, buffer and titrating solutions, the color change at the end point is greatly improved; and the color change with a pure calcium solution is both sharp and accurate.

A further disadvantage of the former method was that very small quantities of copper and manganese interfere with the test and no end point can be obtained. In fact, as little as 0.1 ppm of copper would prevent an end point. However, with the revised buffer solution the presence of copper, iron or manganese offers no interference.

* With W. H. & L. D. Betz, water-conditioning specialists, Philadelphia, Pa.

Australian Central Station to Use High Pressure and Temperature

To deal with estimated electrical demands in New South Wales, Australia, it will be necessary to increase the generating capacity from its present 750 megawatts to about 2000 megawatts by 1960. One of the stations in this expansion program, Pyrmont B, which is now being constructed near Sydney, will have an ultimate capacity of 200 megawatts. According to *Engineering*, this plant will include four boilers, each capable of supplying 430,000 lb of steam per hr at 1250 psig and 950 F. These units, which are being designed and manufactured by International Combustion, Ltd., will be the largest high-pressure boilers in the British Empire. They will be pulverized-coal-fired through corner-firing tilting burners to aid in controlling steam temperature and furnace slagging. Each boiler will supply a three-cylinder turbine driving an alternator generating three-phase, 50-cycle current at 33 kv.

Business Notes

De Laval Steam Turbine Co. announces that The Superheater Company Ltd. of Canada (in conjunction with its affiliate, Combustion Engineering Corp. Ltd.) has been appointed to represent it in the Provinces of Newfoundland, New Brunswick, Nova Scotia, Prince Edward, and Quebec.

Beaumont Birch Co. has enlarged its line of coal, coke and ash-handling equipment and has appointed H. R. Pursel head of its Hydraulic Materials-Handling Systems Department.

Richard Cutts, Jr., has been named manager of sales for the Central Station Division of the **General Electric Company's** Apparatus Department.

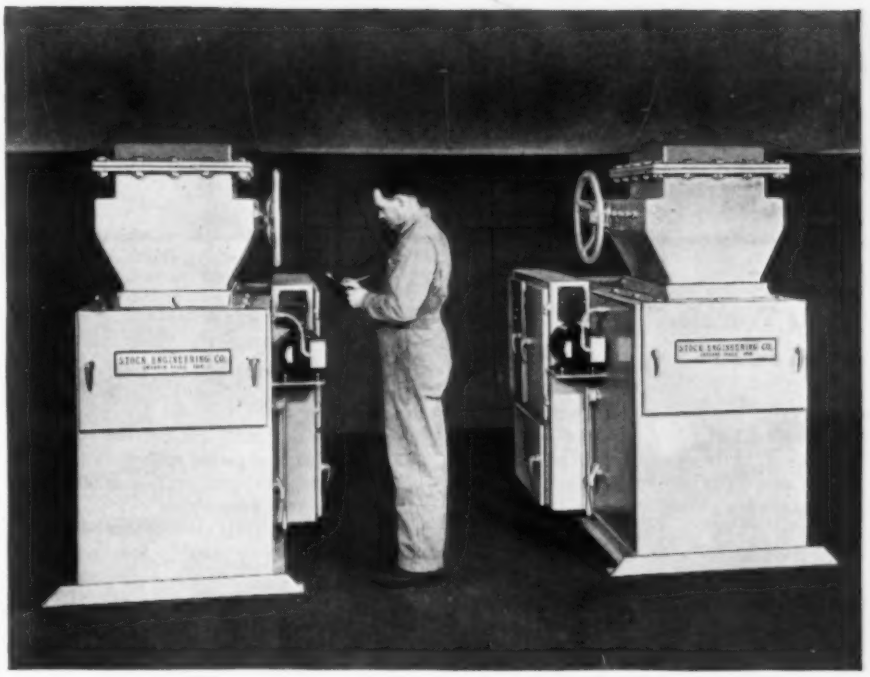
Graver Water Conditioning Co., New York, has appointed Henry T. Sulcer general manager. Aiding him (in Chicago), as assistant general manager, is E. W. Welp, formerly sales manager of the Graver Water Treating Division. S. D. Barr has been advanced to general sales manager with offices in New York.

Pacific Pumps, Inc., has appointed H. A. Puls as its sales representative in the southeastern section of the United States with headquarters in Birmingham, Ala.

Westinghouse Electric Corp. has recently named A. A. Johnson manager of central station engineering to succeed Dr. C. F. Wagner who has become consulting engineer for the Company.

The Dampney Co. of America, Hyde Park, Mass., has arranged with Industries Service & Equipment Co., of Erie, Pa., to represent it in Erie, Crawford and Warren counties.

Yarnall-Waring Co., Philadelphia, has announced the following appointments in its sales organization: John A. Steer, from Philadelphia to New York as district manager, succeeding H. S. Webster, who has retired; and J. B. Ambler as sales representative in the Denver District.



CLEAN BOILER ROOMS RESULT WITH

DUST-TIGHT S-E-CO. COAL SCALES

S-E-Co. Coal Scales are built with a steel plate body which is welded into one dust-tight unit. Forged steel hinges, specially designed latches and rubber gaskets make the access doors dust-tight. As a result, the complete scale unit is dust-tight. In fact, special scales are available which will be dust-tight even with 5 pounds of internal air pressure.

For clean boiler rooms, investigate the dust-tight design of S-E-Co. Coal Scales.

Write for bulletin.

STOCK ENGINEERING COMPANY
715C Hanna Building ★ Cleveland 15, Ohio

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

"Heat Transfer," Vol. I

By Max Jakob

This book is a treatise on past literature and covers a history of material leading to the present state of our knowledge. The subject matter is presented in such a manner that review of the original papers is not necessary. The material included in Vol. I is concerned mainly with conduction and convection, although it does cover the basic equations of all three phases of heat transfer. The sections dealing with radiation and the combination of the different modes of heat transfer will be presented in Vol. II which is now being prepared. A considerable part of the first volume is devoted to the understanding of physical properties of matter that play significant rôles in the transfer of heat. Each of these sections on conduction and convection contains straight solutions, analogies, and similarity treatments supplemented by graphical and experimental methods and techniques.

There is a review of basic equations which covers the laws governing all phases of heat transfer. The section on the transfer of heat by radiation presents such highlights as Stefan-Boltzmann Law, Kirchoff's Law, Lambert's Law, Wein's Law, Planck's Law, space density, etc. Rules for the influence of pressure, temperature, and structure upon the conductivity of gases, liquids and materials such as insulators, refractories, metals, fine powder, alloys and porous loose material, amorphous material and crystalline nonmetallic materials are well presented.

The book goes on to develop formulas for heat conduction in a steady state which apply to the most common engineering shapes such as the plane plate, cylinder, spheres, rods and fins of several different profiles. These relationships are developed for systems that have no heat gains or losses, with (*a*) internal heat generation, or (*b*) heat dissipation to the environment or (*c*) their combination.

In addition to formulas for conduction with periodic and non-periodic temperature changes without heat losses or gains, there is reviewed the condition at which heat conduction takes place at variable temperature with internal heat generation while heat is dissipated to the environment. Applications of the unsteady state equations are followed by a review of the mathematical methods, numerical methods, graphical methods and experimental analogy methods used for the solutions of heat conduction problems.

The remainder of the text is devoted to the transfer of heat by convection. Similarity equations are developed after a review of some of the general features of heat convection and analytical solutions of convection equations. Experiments on free and forced convection are reviewed and correlated, and optical methods for determining heat transfer by convection are reviewed. Heat convection which includes changes of phase such as heat transfer in evaporation and condensation brings the text to a close.

The author's approach assumes that the reader has some familiarity with the material in addition to a knowledge of calculus which is required for the full understanding of the book. It could serve as a text for graduate or undergraduate students and may be particularly useful to men concerned with the transfer of heat by conduction and convection.

Standards of Tubular Exchanger Manufacturers Association, Second Edition

Compiled by the Technical Committee of the Association, Thomas H. Miley, Chairman, and Townsend Tinker, Editor

This industry-sponsored book should be of value to anyone concerned with the design, manufacture, specification, purchase, operation or maintenance of tubular heat exchangers. There are eight sections which make up the work: General Fabrication and Performance Information, Heat Exchanger Nomenclature, Fabrication Tolerances, Mechanical Standards for Class R Heat Exchangers, Mechanical Standards for Class C Heat Exchangers, Material Specifications, Thermal Standards and Reference Data, and Installation, Operation and Maintenance of Shell and Tube Heat Exchangers.

The purpose of the first edition was to set forth recommended standards for mechanical and thermal design and construction of cylindrical shell and bare tube heat exchangers. A wider scope is covered in the new edition which contains much new information that was not available for publication in 1941.

There are numerous tables listing detailed standards and drawings showing typical construction arrangements. Section 7, covering Thermal Standards and Reference Data, includes some particularly valuable heat-transfer and mean-temperature-difference correction curves, nomographs relating to thermal conductivity and specific heats, and graphical representations of viscosity-temperature relationships.

There are 94 pages, $8^1/_2 \times 11$ in., and the price of the book is $3.00 for the paper-cover edition and $4.00 for the fabrikoid-cover edition.

Refractories

Those who design, use, purchase, construct, and supervise the operation of equipment requiring refractory materials will find this handbook of considerable interest. Beginning with the history of refractories and their sources of supply, the book explains steps in their manufacture. Another section is devoted to the uses of refractories in iron and steel plants, the production of non-ferrous metals, the rock products industries, the glass industry, the pulp and paper industry and in steam generators for stationary plants, marine equipment and railroad locomotives. The complete line of products of General Refractories Company, including refractory brick, mortars, plastics and castables, is described, and there is a section that is devoted to the properties and behavior of refractories.

There is a great deal of information on construction with refractories and tables to simplify the numbers and type of brick required. Trade practices are set forth, along with information concerning the ordering and shipping of refractory materials. A very useful glossary of terms used in the refractory industry and a detailed index complete the book.

Heretofore the refractories industry has been but little publicized. This attractively printed and illustrated handbook supplies information that has not been readily available. Many of the illustrations are in color, and the photographs of industrial applications are particularly outstanding. "Refractories" contains 272 pages, is durably found between hard covers and may be obtained for $5.00 by writing to General Refractories Co., 1520 Walnut St., Philadelphia 2, Penna.

Reveiw of Current Research

Over 4000 current college and university research projects in engineering subjects, representing expenditures of over $35,000,000 are listed by title in the 1949 edition of this book published by the Engineering College Research Council of the American Society for Engineering Education.

Entries in the book from 82 educational institutions which hold membership in the Research Council describe the administrative policies for conducting engineering research and list the responsible personnel, research expenditures and the titles of engineering research studies currently active at each institution.

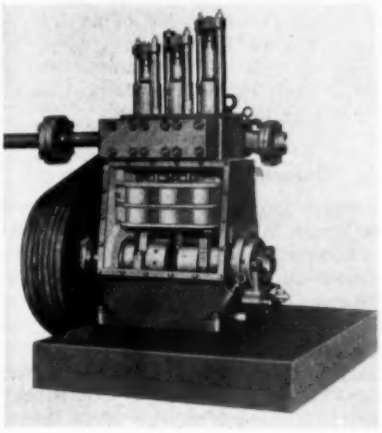
Use of the volume is facilitated by a breakdown of research projects according to the engineering departments involved, and by a complete index to research project subjects. In view of the increasing amount of research carried out in universities under sponsorship by industry and government, this section of the review is of timely interest.

Copies of the book, paper bound and including more than 180 pages, are available for $1.75 from the Engineering College Research Council, College of Engineering, State University of Iowa, Iowa City, Iowa.

NEW EQUIPMENT

Direct-Flow Pump

A new series of 5-in. direct-flow pumps is announced by The Aldrich Pump Co. of Allentown, Penna. Included in the series are triplex, quintuplex, septuplex and nonuplex pumps in sizes ranging from 100 hp with the triplex to 275 hp for the nonuplex. To assure minimum replacement cost and time requirements when handling corrosive liquids, the fluid end of these



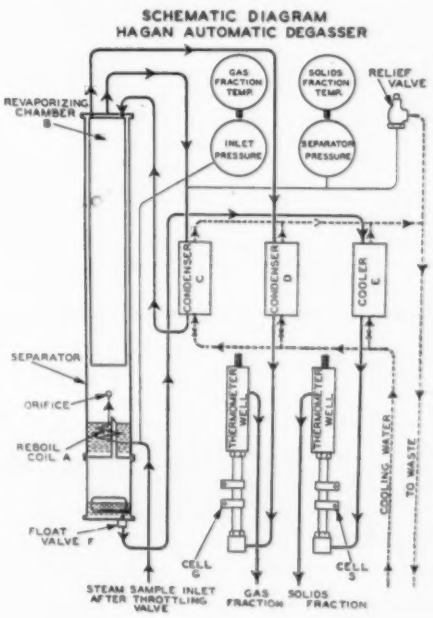
pumps is sectionalized and composed of separate units, including working barrel, stuffing boxes, suction manifold and valve units. The pump frame is a semi-steel casting of rigid design, while the crankshaft is made of forged steel. Drive may be by internal combustion or steam engine, electric motor or steam turbine, and it may be direct or through gearing, separate speed reducer, or belt.

Heat Exchanger

Ross Heater & Mfg. Co., of Buffalo, N. Y., now has under mass production an all-stainless-steel heat exchanger which is completely standardized and for which a full stock of component parts is maintained. Identical in design and capacities to the Ross BCF exchanger, the new model, Type SSCF, utilizes stainless steel to avoid contamination of fluids or corrosion by fluids. It is available in a complete range of sizes tested to 450 psig to withstand strenuous usage.

Automatic Degasser

Announcement of the Hagan Automatic Degasser for the determination of steam purity has been made by the Hagan Corp. of Pittsburgh, Penna. The new de-

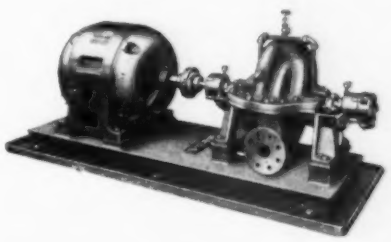


vice produces an approximately 50–50 split of a flowing steam sample, one fraction of the condensed steam containing dissolved solids that may be present and the other, dissolved gases. It was invented by H. M. Rivers of Hall Laboratories, Inc., and has undergone extensive field tests where it has given trouble-free automatic operation. Carbon dioxide has been eliminated from the fraction containing dissolved solids, while ammonia has either been eliminated or reduced to the point that it is no longer a factor in conductivity measurements.

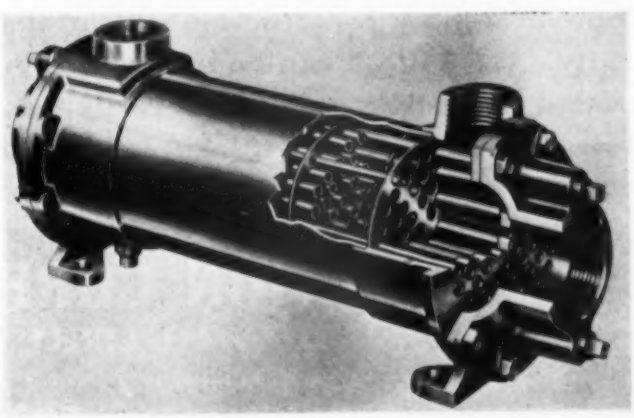
The fraction of the condensed steam containing dissolved solids free from gases is run through a cell in which its conductivity may be accurately measured. One feature of the new apparatus is its automatic operation which avoids the necessity of frequent attention and valve twisting. Contamination of flowing steam and condensate is prevented by the use of stainless steel wherever contact might be made. The time interval between entrance of steam and measurement of conductivity is about one minute, which makes for rapid correlation of data obtained from the degasser with steam flow and superheat temperature. Steam consumption of the instrument is claimed by the manufacturer to be about 30 lb per hr.

Two-Stage Pump

A new two-stage volute centrifugal pump, Type TL, has been developed by the Warren Steam Pump Co., Inc., Warren, Mass. Features include water-cooled construction, duplex angular-contact ball-thrust bearing, labyrinth-type seal, heavy horizontal-split casing with flanged-bearing supports, inter-stage seal against by-passing, suction pressure only on both stuf-



fing boxes, renewable protective shaft sleeve, and hydraulically balanced back-to-back impellers. The pumps are built in capacities up to 825 gpm and for total heads up to 800 ft.



Fine-Screen Strainers

Yarnall-Waring Company, Philadelphia 18, Pa., has provided new details on fine screens for its "Yarway" strainers. These screens in the screwed strainers are made of Dutch-weave Monel-wire filter cloth having small triangular openings which provide fine straining and large free area with mechanical strength greater than that of ordinary square-mesh screens. Ratios of open area of screen to inside area of pipe range from five and one half times for the 1/2-in. strainer to three and one fourth times for the 2-in. strainer.

New Catalogs and Bulletins

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York 16, N. Y.

Air Conditioning Equipment

Bulletin 3158-B, issued by Buffalo Forge Co., is a 16-page release on central air-conditioning equipment. There is a complete description of type "PLCW" equipment with photographs of erected units. One section discusses the selection of cooling and heating coils, and there are installation and maintenance instructions. A full-page psychrometric chart adds to the value of the bulletin.

Ball Valves

Venturi-ball valves are described in the 16-page bulletin No. 103 just released by the Paul Valve Corp. The catalog is well illustrated and covers principles of operation and engineering data on bar-stock valves, cast and stainless-steel valves, and forged valves. Methods of valve operation are enumerated, and typical designs are illustrated.

Centrifugal Pumps

Buffalo Pumps, Inc., has brought out a 24-page bulletin No. 955-N on double-suction, single-stage centrifugal pumps. Along with illustrations of typical installations and pump-construction details, the catalog contains a rating table for equipment selection and a listing of approximate dimensions. There is also a section devoted to Underwriter fire pumps.

Centrifugal Pump Selection

Allis-Chalmers has issued a 16-page booklet entitled "Handy Guide to Selection of Centrifugal Pumps." Applications, construction features, sizes and capacities, and types of drives are presented for close-coupled and pedestal type, single- and double-suction, single- and two-stage pumps. There are also sections describing fire, multi-stage, self-priming, process, marine, solids-handling, and paper-pulp pumps.

Chemical Cleaning Service

A four-page bulletin explains the chemical cleaning service offered by Sumco Products, Inc. This service may be used for steam boilers, condensers, feedwater heaters, economizers, stills, heat-exchangers, storage tanks, evaporators, and process equipment. The bulletin has photos of mobile equipment for chemical cleaning.

Coal Handling

Gifford-Wood Co. has published a new bulletin describing 14 case histories of coal handling and storage systems. The installations were all based upon the use of any one of four basic types of storage and handling systems advocated by Gifford-Wood. The bulletin explains how these systems may be adapted to suit varying conditions of space, capacity, climate and allowable initial cost. It also tells why specific selections of basic designs were made.

Combustion Control

Combustion control is the subject of an 8-page technical bulletin No. 103 recently prepared by General Power Plant Corp. It contains an exposition of the nature of haze and its use as a combustion index. There is also a description of devices ranging from the simplest auxiliary controls for addition to present systems up to complete Robot-Eye installations. The information includes a discussion of methods of control for all hydro-carbon fuels, including oil, gas and bituminous coal of varying analyses, whether burned separately or together.

Corrosion Service Piping

Bulletin 485, issued by Taylor Forge & Pipe Works, is a comprehensive treatment on stainless steel and nickel alloy anti-corrosion and anti-contamination piping. Economics, standards, advantages of welding, technical data, design suggestions, and dimensional information on stainless fittings and flanges are included in the 32-page attractively illustrated bulletin.

One Layer of R & I Insulating Block Does the Work of *Two*

R & I Insulating Block is a high as well as low temperature block, permitting *single* layer construction. It is equal in insulating efficiency to double-layer insulation at all temperatures up to 1800°. Can also be used at low temperatures. The one layer block construction will cut insulation cost greatly. R & I Block can be used wherever block insulation is required. Can be easily handled and easily cut. It is unaffected by water and steam. Furnished in thicknesses up to 4½" and in standard sizes. *Ask for Bulletin I-76.*

REFRACTORY & INSULATION CORP.

NEW YORK 5, N. Y. 124 WALL STREET

Chicago 4, Ill. Newark 2, N. J. Philadelphia 2, Pa.

Combustibles Recorder

Design improvements and new applications for the Combustibles Recorder are featured in a 16-page bulletin now being distributed by Bailey Meter Co. Drawings and photographs explain the operation of this electronic-type instrument which operates on the catalytic combustion principle. Either air or electrically operated control of combustibles content may be had with the recorder, which may be applied to boiler furnaces, rotary kilns, industrial furnaces, and chemical processes.

Cooling Towers

An informative 16-page booklet entitled "Operating and Maintaining Mechanical Draft Cooling Towers" has been prepared by the C. H. Wheeler Manufacturing Co. One section is devoted to application and performance of cooling towers, another to placing towers in operation, and a third to maintenance. Cartoons are effectively used to illustrate some of the precautions necessary for cooling-tower operation and maintenance.

Deaerating Heaters

A new 8-page bulletin on two-stage deaerating heaters has been published by Graver Water Conditioning Co. It outlines the principles of deaeration, describes heater design, operation and application, and explains distinctive features. In addition to showing vertical and horizontal types of heaters, the bulletin includes flow sheets of this apparatus in conjunction with other feedwater equipment in intermediate-pressure, high-pressure, and central-station boiler plants.

Instrument Valves

Bulletin No. 491, providing information on drop forged steel instrument valves for meter, gage, instrument, and other small lines, has been issued by Edward Valves, Inc. Dimensions, weights, prices, and operating data are included on these new valves, which have a rating of 6000 psi at 100 F or 1500 psi at 850 F with carbon steel bodies, and 1500 psi at 1000 F with stainless steel bodies.

Multi-Jet Condensers

Schutte and Koerting Co. have recently released Bulletin 5-A which pictures and describes SK Low-Level Multi-Jet Condensers. Cutaway views and sectional drawings are used to show construction, and installation photographs and colored diagrams illustrate typical applications. Sizes, capacities, overall dimensions, and weights of condensers are also given in the 12-page release.

Multi-Stage Turbines

An exceptionally attractive and informative 24-page bulletin on multi-stage turbines has been published by the De Laval Steam Turbine Co. The economy of producing power as a by-product is explained in a series of diagrams showing utilization of available heat under different operating conditions, while another set of sketches details basic turbine types, operating conditions, and specific applications. Turbine construction is illustrated by an unusually effective cutaway view and by photographs of component parts. There are also diagrammatic representations of governors and controls, and photographs of representative installations.

Positive Displacement Pump

A 4-page bulletin on "Controlled Floating Vane Positive Displacement Rotary Pumps" has been prepared by the Chicago Laboratory & Engineering Co. There are photographs showing the assembled pump and individual component parts. The pumping action is explained by means of a series of four diagrams, and a table listing available models and sizes is included.

Rust Preventives

An attractive 16-page booklet on "Rust-Ban" products has been issued by Esso Standard Oil Co. and contains detailed recommendations for the selection of rust preventives as well as pertinent information on the use of these coatings. Procedures for using rust preventives are also explained. Mention is made of laboratory tests for evaluating rust preventives, and the advantages of rust-prevention surveys are cited.

Steam Humidifiers

Armstrong Machine Works has revised its 12-page Bulletin No. 1772 describing steam humidifiers, including two new air-controlled models. It contains a discussion of dry air problems, tables on relative humidities and regain of hygroscopic materials, and complete data on the operation and installation of humidifiers.

Water Conditioning

A new 8-page bulletin on "Water Conditioning Processes and Equipment" explains the activities of the Graver Water Conditioning Co. in research in water conditioning for boiler plant, process work, and general industrial and municipal use. It includes illustrations of installations of hot-process and zeolite softeners, demineralizers, clarifiers, and filters.

Water Treatment

A 20-page bulletin No. 610 on water conditioning has been issued by Elgin Softener Corp. The information on the design and application of water conditioning equipment covers zeolite water softeners, water-treating chemicals, water-conditioning systems for boilers and processing, water softener modernization, zeolites, water filters, rust and odor removers and aerators. An improved water softener is described in detail.

It's easier to store and reclaim coal with a SAUERMAN POWER SCRAPER

Two Sauerman Power Scraper machines with self-propelled tail towers. One unit handles up to 250 t.p.h., the other 400 t.p.h. Each is operated by one man stationed in comfortable cab at head end.

The trend in coal storage methods, as exemplified by Sauerman Power Scraper systems, features easier work for the operator as well as faster movement of coal by the equipment.

All recent improvements in Sauerman coal-handling equipment have reinforced the ability of the scraper operator to spread the coal adequately, to pack the coal uniformly, and to operate effectively in all kinds of weather without inconvenience.

Coal piles built the Sauerman way are sealed against spontaneous combustion. The Crescent scraper bucket, in moving across the pile, rakes the fines into the voids, eliminating air pockets and thoroughly compacting the coal. Users agree that coal properly piled by a Sauerman machine will stand years without deterioration.

WRITE FOR THE SAUERMAN COAL STORAGE CATALOG.

SAUERMAN BROS., INC. 550 S. Clinton St., Chicago 7, Ill.

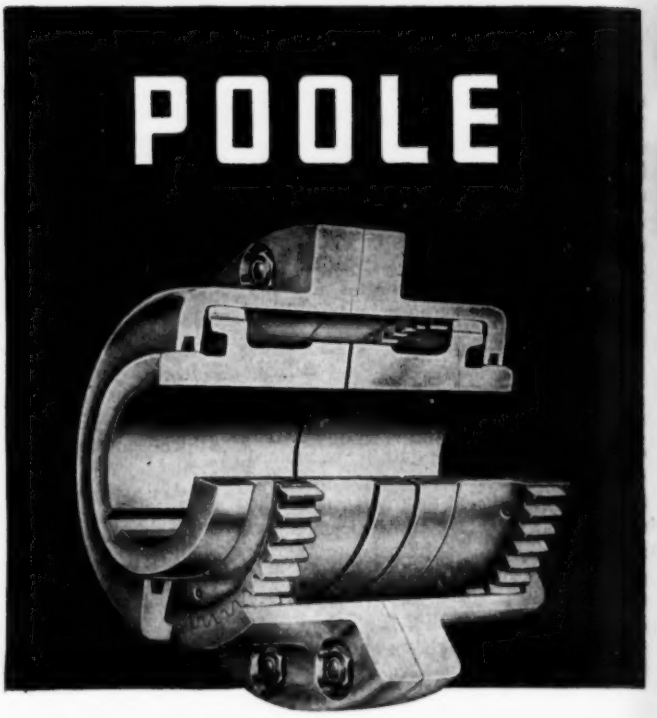
The IMO Pump can be operated at motor and turbine speeds. It is ideal for direct connection and integral mounting. Excepting for the flow and vaporization characteristics of the fluid being pumped, there's practically no limit to the speed at which an IMO Pump can be operated.

IMO Pumps can be furnished for practically any capacity and pressure required for oil, hydraulic-control fluids and other liquids.

Send for Bulletin I-147V.

IMO means I MOVE OIL

IMO PUMP DIVISION of the
DE LAVAL STEAM TURBINE CO.
TRENTON 2, NEW JERSEY



A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST

FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY WOODBERRY, BALTIMORE, MD.

Advertisers in This Issue

Air Preheater Corporation, The 56
Aldrich Pump Co., The 24
Armstrong Cork Company 52
Armstrong Machine Works 60
Theo. Audel & Company, Publishers ... 60
Bailey Meter Company 31
C. O. Bartlett & Snow Company, The .. 28
Bayer Company, The 30
Beaumont Birch Company 66
W. H. & L. D. Betz 27
Bird-Archer Company, The 12
Buell Engineering Company, Inc. 32
Buffalo Forge Company 15
Cochrane Corporation 21
Combustion Engineering—Superheater, Inc. ..... Second Cover, 22 and 23
Crane Co. 14
De Laval Steam Turbine Company 72
Diamond Power Specialty Corporation. ..... Third Cover
Engineering Company, The 20
Ernst Water Column & Gage Company 18
Gifford-Wood Co. 13
Grinnell Company, Inc. 9
Hagan Corporation ..... 16 and 17
Hall Laboratories ..... 16 and 17
Hays School of Combustion 58
Johns-Manville 19
Northern Equipment Company 2
Pacific Pumps, Inc. 61
Pittsburgh Piping and Equipment Company 26
Pittston Company, The 25
Poole Foundry & Machine Company ... 72
Wm. Powell Company, The 38
Refractory & Insulation Corporation .. 70
Reliance Gauge Column Company, The 8
Research Corporation 29
Sauerman Bros., Inc. 71
Benjamin F. Shaw Company .. Fourth Cover
Steel & Tubes Div., Republic Steel Corporation ..... 6 and 7
Stock Engineering Company ..... 63 and 67
Swartwout Company, The 11
Terry Steam Turbine Company, The ... 10
Thermix Corporation, The ..... 4 and 5
Vulcan Soot Blower Corporation 62
Whiton Machine Company 64
L. J. Wing. Mfg. Company 65
Yarnall-Waring Company 3